Effects of Ankle Taping Upon Strength Decrement and Surface Temperature of Knee Flexors and Extensors in Submaximal Treadmill Running.

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ABSTRACT

The primary purpose of this study was to investigate the effects of ankle taping upon the strength decrement of the knee flexors and extensors in a submaximal treadmill running performance. A secondary purpose of the study was to determine the effects of ankle taping upon the surface temperature changes in five selected anatomical areas of the thigh and knee joint following submaximal treadmill running. A sub-purpose of this investigation was to determine the relationship between strength decrement and skin temperature elevation of the knee flexors and extensors.

Sixty high school and college males volunteered as participants in this study which was conducted during the spring semester of the 1971-72 academic year. Following a counterbalanced testing schedule, the subjects completed a ten-minute treadmill run at six miles per hour and at a 10 per cent grade under each of two conditions: (1) ankles taped and (2) ankles untaped. Static strength tests of the knee flexors and extensors were administered to the subjects before and after each treadmill run to determine the effects of ankle taping upon strength decrement of these muscle groups. Surface temperature measurements of five thigh and knee joint locations were also taken before and after the treadmill runs. The anatomical sites included the belly of the rectus femoris, quadriceps tendon, lateral collateral ligament, medial collateral ligament, and the belly of the biceps

femoris. The temperature increases of the five areas were monitored in both legs until each area had peaked in elevation.

A t-test for significance of the difference between correlated means was utilized to determine the significance of the mean strength decrement scores and also for the surface temperature gains. A randomized block analysis of covariance procedure was employed to compare the differences between the two experimental conditions concerning the amount of strength decrement in the knee flexors. A randomized block two-by-two factorial analysis of covariance procedure was utilized to determine whether or not differences existed between the taped and untaped ankle conditions with reference to strength decrement in the knee extensors. This was necessary because the knee extensors were measured for strength separately. A randomized block two-by-two factorial analysis of covariance procedure was also used to determine differences between the two conditions regarding skin temperature elevation in the five anatomical locations of the thigh and knee joint. Pearson product moment coefficients of correlation were computed to determine the relationship of skin temperature increases in the five body locations and strength loss of the knee flexors and extensors.

Within the limitations of this study, the results indicated that:

1. Ankle taping apparently does not contribute to strength decrement in the knee flexors and extensors during a stressful running performance.

2. There is some evidence that ankle taping retards the normal surface temperature elevation of the knee extensors during strenuous anterior-posterior movement of those muscles.

3. Ankle taping does not appear to affect the normal skin temperature elevation of the quadricep tendons, lateral collateral ligaments, medial collateral ligaments, and biceps femoris muscles during submaximal running.

4. The relationship between skin temperature elevation in the thigh and knee joint and strength decrement of the knee flexors and extensors as a result of a strenuous running performance is negligible.

CHAPTER I

INTRODUCTION

In recent years the continued growth in the popularity of sports has led to a vast increase in number of participants at both the amateur and professional levels. If the projections of sociologists and professional recreators are credible concerning the expansion of leisure within the next fifty years, sports will continue to flourish and become even more engrained into the American way of life. The surge of national interest in athletics has created an impact on society in varied fashion; one such reaction to the sport phenomenon has been an increased need for prevention and medical care of athletic injuries. This has resulted in the relatively new and specialized field of sports medicine.

Sports medicine is presently recognized in much of the world as a specialty of medical practice. The American College of Sports Medicine was founded in 1954. Its membership is composed of persons involved in health and physical education, physiology, medicine, and other professions related to sports. The association of 1,300 members sponsors annual scientific meetings, publishes a newsletter on a quarterly basis, prepared the Encyclopedia of Sport Sciences and Medicine, and publishes the Journal of the College of Sports Medicine and Physical Fitness, a most popular periodical in the related fields of athletics and physical education. A significant landmark for sports medicine in

America was the establishment in 1955 of the American Medical Association's Committee on Injuries in Sport.[1]

Another organization that has been instrumental in the advancement of knowledge concerning the prevention and care of athletic injuries is the National Athletic Trainers' Association. The group was founded in June of 1950 at an organizational meeting in Kansas City, Missouri and set as its primary objective "to advance, encourage, and improve the athletic training profession in all of its phases and to promote a better working relationship among those persons interested in the problems of training."[2] The association has progressed from an unrefined origin to a mature science that requires a unique body of knowledge. This professional body also publishes a quarterly journal and sponsors an annual athletic training clinic.

Ryan,[3] writing in the Encyclopedia of Sport Sciences and Medicine, reported that the greatest possibility for future achievements in the related areas comprising sports medicine lies in the area of preventive medicine. Professional personnel in these areas are aware that prevention of injury is the number one priority and primary responsibility of anyone responsible for the physical training of athletes. Athletic trainers and team physicians staunchly adhere to the old adage, "An ounce of prevention is worth a pound of cure." It is realized that the

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[1]Allan J. Ryan, "Prevention of Sports Injury," Journal of Sports Medicine and Physical Fitness, II (December, 1962), 233.

[2]O. William Dayton, Athletic Training and Conditioning, (New York: The Ronald Press Company, 1960), p. 3.

[3]Allan J. Ryan, "Sports Medicine In the Future," Encyclopedia of Sport Sciences and Medicine, ed. Leonard A. Larson, (New York: The MacMillan Company, 1971), p. xlvi.

time spent devising ways and means to treat athletic injuries could be immensely reduced if coaches, trainers, and all affiliated personnel displayed an intimate knowledge of the preventive aspects of sports medicine.

Perhaps at no other time in American history has greater emphasis been placed on the prevention of sports injuries than the present. Hirata,[4] football team physician at Yale University, asserted that physiologists, cardiologists, orthopedists, biophysicists, and statisticians are all contributing to a steadily mounting reservoir of literature on athletes and athletics as demonstrated by the increase of Index Medicus listings. A great bulk of this material is related to the prevention of athletic injuries. Recently the United States House of Representatives Subcommittee on Commerce and Finance conducted a hearing on the relationship of the use of artificial turf and football injuries.[5] A survey of injuries at the University of Washington during the 1969 and 1970 football seasons which revealed that injuries were more than three times as frequent on dry as on wet synthetic turf, prompted the investigation by the House Subcommittee.

Morehouse and Rasch[6] have contended that, notwithstanding the increased concern about the incidence of sports injuries and improvement

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[4]Isao Hirata, Jr., The Doctor and the Athlete, (Philadelphia: J. B. Lippincott Co., 1968), p. v.

[5]News item in The Morning Advocate, Baton Rouge, Louisiana, November 2, 1971.

[6]Laurence E. Morehouse and Philip J. Rasch, Sports Medicine for Trainers, (Philadelphia: W. B. Saunders Company, 1963), p. 9.

of professional standards of trainers, some trainers still persist in the use of questionable practices that are designed to hasten an athlete's recovery from injury, improve his performance, or allay his fatigue.

The etiology of sports injury is complex because numerous factors tend to contribute to the incurrence of athletic injuries. The more prevalent causes of athletic injuries generally are due to either lack of physical conditioning, improper environment, or inadequate equipment.

A very important concern of team physicians, coaches, and doctors regarding the injury problem is the prevention of knee injuries. The knee is the most commonly injured major joint in athletes as attested to by several studies reported in the literature. Some possible causes of knee injuries mentioned in the literature are lack of leg strength, fatigue, improper mechanics of movement, type of shoe (practice or game), time of the season, playing position, climatic conditions, type of turf (hard, soft, or artificial), body build, and ankle taping.[7]

Injuries to the thigh and ankle are also common athletic injuries, especially in football. The muscles most often injured in football are the hamstrings, the quadriceps, and the calf muscles. Although some injuries are inevitable, especially in highly competitive contact sports, most experts in the athletic training profession agree that many injuries could be avoided if proper precautionary measures were followed.

Two of the possible causes of knee injuries, ankle taping and fatigue, are topics of concern in this study. There has been prolonged controversy concerning the value of supporting the ankle during

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[7]John Charles Wells, "The Incidence of Knee Injuries in Relation to Ankle Taping" (unpublished Master's thesis, Indiana University, Bloomington, 1969), pp. 2-3.

competition. Rarick and others[8] indicated that the taping of normal ankles prior to contact sports is recommended by most trainers and team physicians with long experience in treating athletic injuries. Conversely, some coaches, trainers, and team physicians theorize that taping the ankle places undue strain on the knee and therefore increases the incidence of knee injuries. It is an issue that remains unsettled, and a topic that is still frequently debated.

There is general agreement that preventive ankle taping lends support to the ankle during stress situations, but since preventive ankle taping is designed to restrict the inversion-eversion movement of the ankle joint, some authorities believe the taping procedure reduces the knee's ability to dissipate the force of a lateral blow. For this reason, in addition to the suspicion that ankle taping produces a constriction of blood flow in the lower extremities, adversaries of preventive ankle taping contend that the knee is more susceptible to injury when the ankles are taped.

Hirata,[9] a proponent of the above school of thought, stated that the rigid policy of requiring ankle strapping of every ankle for every workout and game was abandoned better than ten years ago at Yale University. He further stated that knee injuries have not been a frequent problem since that time, perhaps because of the change in policy concerning preventive ankle taping.

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[8] G. Lawrence Rarick and others, "The Measurable Support of the Ankle Joint by Conventional Methods of Taping," Journal of Bone and Joint Surgery, XLIV (September, 1962), 1183-1190.

[9] Hirata, op. cit., pp. 252-253.

Opponents of the preventive ankle taping policy also have questioned the justification for the amount of time consumed in taping ankles, and the expense incurred from the purchase of tape. Some schools reportedly spend thousands of dollars annually on adhesive tape.

The term, fatigue, is difficult to adequately define because of its varied usage. Notwithstanding this fact, researchers have attempted to measure this condition in a variety of ways. In the physical education profession, the use of strength decrement as an index for fatigue has become commonplace. Clarke,[10] a pioneer in using strength decrement as a fatigue index, and associates conducted a study which indicated that a loss of strength because of fatigue may serve as an indication of a predisposition toward injury. By exercising conditioned subjects for a period of three weeks and an unconditioned group for two weeks until complete muscular fatigue was reached each day, the researchers were able to determine from post-exercise strength and speed of recovery tests that the general strength recovery was much more rapid in the conditioned group. They also concluded from the study that the higher the level of strength that can be developed through preconditioning drills, the greater will be the reduction of injury potential. LaCava[11] concurred with the above conclusion by declaring that the inability of the athlete to produce a determined quality of muscular work is often the basis of acute fatigue which causes the muscular masses to be more

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[10]H. Harrison Clarke, Muscular Strength and Endurance in Man (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1966), pp. 90-101.

[11]G. La Cava, "The Prevention of Accidents Caused by Sport," Journal of Sports Medicine and Physical Fitness, IV (December, 1964), p. 293.

easily ruptured and results in uncoordinated athletic action, thereby, explaining the possible origin of many sporting accidents.

Cerney[12] avowed that the number of football injuries is in direct proportion to the degree of mental and physical condition of the players. Fatigue and "tiredness" play an important role in late season injuries. This is not only a problem of the season but may be noted in the time segments of a football game because injuries most often occur near the end of quarters. Morehouse and Rasch[13] reported the highest incidence of football fatalities to occur with athletes who had played in the game from twenty-six to forty-five minutes. They concluded that fatigue probably plays a large part in the occurrence of injuries during this time. Klafs and Arnheim[14] noted that fatigue is one of the possible causes of hamstring strains. Abbott and Kress[15] who have studied the problem of knee injuries for years at the United States Military Academy, stated that unilateral weakness of the musculature surrounding the knee joint is a determining factor in the occurrence of knee injuries. Dayton[16] stated that in a state of fatigue, the muscles stiffen and contribute to a considerable loss of reaction which may lead to an injury.

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[12] J. V. Cerney, Athletic Injuries (Springfield, Illinois: Charles C. Thomas Publisher, 1963), p. 293.

[13] Morehouse and Rasch, op. cit., p. 136.

[14] C. Klafs and D. D. Arnheim, Modern Principles of Athletic Training (St. Louis: C. V. Mosby Co., 1963), p. 318.

[15] Howard G. Abbott and John B. Kress, "Preconditioning in the Prevention of Knee Injuries," Archives of Physical Medicine and Rehabilitation, L (June, 1969), 326.

[16] Dayton, op. cit., p. 40.

Knee strength is dependent upon the powerful extensors of the knee, the quadriceps femoris muscle group, and the flexors of the knee, the hamstrings muscle group. The quadriceps femoris muscle group, consisting of the rectus femoris, vastus lateralis, vastus intermedius, and vastus medialis muscles, provides for anterior stabilization of the knee joint and helps to protect the knees when lateral blows are sustained. The hamstrings muscle group, including the biceps femoris, semitendinosus, and the semimembranosus muscles, furnishes medial, lateral, and posterior support to the knee during extension. This support, thereby, gives protection against the hinging effect of the knee joint during stress situations.

Cerney[17] has stated that the knee is nothing without the quadriceps, agreeing with other sports medicine personnel who believe in the old axiom, "The knee is no stronger than the quadriceps muscles." Since there is unequivocal evidence that the quadriceps muscles lose tone faster than any other muscle group, authorities declare that preseason and regular conditioning of this muscle group cannot be overemphasized. Increased attention to the imbalance in development of the hamstrings and quadriceps has become a recent trend in athletic training. The tendency in the past has been to give far greater attention to the quadriceps than the hamstrings. Neither should take precedence over the other because maximum development of strength in both muscle groups is invaluable to the protection of the vulnerable knee joint.

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[17]Cerney, op. cit., p. 547.

Although the major stability for the knee joint comes from the aforementioned muscle groups, there are two pairs of ligaments which contribute to the antereoposterior and medial-lateral stability of the knee. The cruciate ligaments provide antereoposterior stability while the medial and lateral collateral ligaments add stability in the lateral plane. Ligamentous injuries are prevalent in sport, especially injuries to the medial and lateral collateral ligaments. The sport of football has the highest incidence of ligamentous injuries, chiefly due to the forces delivered either laterally or medially when the knee joint is in a position of extension.

Another topic of importance in this study is body surface or skin temperature. In contrast to the stability of the internal body temperature, the skin temperature fluctuates widely depending on many factors: (1) structural abnormalities of vessels, (2) abnormalities of vascular control, (3) local effects on vessels from systemic reactions, (4) changes in thermal conductivity of the tissues, and (5) increased heat production in the tissues. In addition, there is a constant exchange of infrared energy between the skin and the environment. The environmental conditions affecting the skin temperature are radiation, conduction, convection, and evaporation. The temperature of the skin is also influenced by environmental temperature, ingestion of food, emotion, sleep, smoking of tobacco, fever, and perhaps other circumstances as yet unknown or not clearly defined.

Every object in nature emits radiant energy as a function of its absolute temperature while simultaneously absorbing some of the energy emitted in its direction by other objects. Consequently, the human body continuously absorbs and emits radiant energy. It is the self-emitted radiant energy within the infrared region that is utilized in the measurement of skin temperature. The use of the radiant heat emission as an index of skin temperature is valid because the skin is a near perfect absorber and emitter of infrared energy.

Researchers involved in skin temperature study generally agree that the skin temperature proper is a result of the combination of heat conduction from the warm inside of the core through the fat and dermal layers to the skin surface, and the convection of heat from the warm internal body by means of the blood flow.

Mathews and Fox[18] reported that the major portion of heat loss during exercise is through evaporation of sweat from the surface of the skin. However, Gershon-Cohen et al.,[19] have stated that heat losses due to sweating do not occur below 30 degrees Centigrade; therefore, the main reasons for heat loss below this temperature are radiation and convection.

Most investigators who have monitored skin temperature changes have assumed that an increase in skin temperature is the result of arteriole dilation, thereby, causing increased peripheral blood flow and rise of surface temperature. Baker and Taylor[20] expressed

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[18]Donald K. Mathews and Edward L. Fox, The Physiological Basis of Physical Education and Athletics (Philadelphia: W. B. Saunders Company, 1971), p. 108.

[19]J. Gershon-Cohen, Jo Ann D. Haberman-Brueschke, and Erich E. Brueschke, "Medical Thermography: A Summary of Current Status," The Radiologic Clinics of North America, III (December, 1965), 413.

[20]Lawrence M. Baker and William M. Taylor, "The Relationship Under Stress Between Changes in Skin Temperature, Electrical Skin Resistance, and Pulse Rate," Journal of Experimental Psychology, XLVIII (May, 1954), 104.

disagreement with the theory by pointing out the inconsistent results of research studies and empirical observations. It was further noted that pale skin with constricted superficial vessels may be hotter than red skin. However, they failed to mention the environmental temperature during the time of the above observations. Allen and Barker[21] stated that the study of skin temperature is an inaccurate method of determining the circulation status except under well-defined circumstances. The researchers indicated that too many determinant factors are involved when measuring the skin temperature to assume a correlation between blood flow and rise of skin temperature.

As commonly reported in the literature, the greatest value of skin temperature measurement lies in the comparison of symmetrical parts of the body. A difference in the temperature of two symmetrical body parts which exceeds two degrees Centigrade usually indicates impaired circulation, and a difference of one degree Centigrade may be significant. This is one of the chief reasons why the technique of measuring skin temperature has value in many medical fields and conditions, among them obstetrics, gynecology, orthopedics, oncology, rheumatology, dermatology, peripheral vascular disturbances, malignancies, and infections. The technique is felt to also have diagnostic and prognostic value in the treatment of Hansen's Disease.[22]

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[21]Edgar Allen and Hines Barker, Peripheral Vascular Disease (Philadelphia: W. B. Saunders Company, 1947), p. 103.

[22]Thomas B. Sabin, "Temperature-Linked Sensory Loss: A Unique Pattern in Leprosy," Archives of Neurology, XX (March, 1969), pp. 257-262.

The measurement of the bilateral symmetry of skin temperature in the human body parts appears to have outstanding potential in the field of sports medicine. To add infrared energy measurement devices as useful diagnostic and prognostic tools to the training facilities of schools and universities, might prove to be a very worthy contribution.

STATEMENT OF THE PROBLEM

Does support of the ankles during muscular exertion of the lower extremities place undue stress as measured by strength decrement on the knee joints? Therefore, the main purpose of this study was to investigate the effects of ankle taping upon the strength decrement of the knee flexors and extensors in a submaximal treadmill running performance. A secondary purpose of the study was to analyze the effects of ankle taping on the skin temperature changes in five selected anatomical areas of the thigh and knee joint following submaximal treadmill running. A subpurpose was to determine the relationship of strength decrement and skin temperature change in the knee flexors and extensors.

NEED FOR THE STUDY

A review of the literature failed to reveal a research study which investigated the effects of ankle taping upon fatigue of the knee joint during submaximal exertion. In a letter of response to an inquiry by the author, Allan J. Ryan,[23] noted athletic team physician at the University of Wisconsin, gave support to the author's finding by stating

[23]Statement by Allan J. Ryan in a letter to the author, December 7, 1971.

that no studies of longitudinal design have been conducted concerning the effects of ankle taping upon knee stress. Studies to date have utilized survey techniques to study the incidence of knee injuries in relation to ankle taping. The small amount of available research findings concerning the issue appears to have added fuel to the flames of the controversy rather than settle it. Much has been said and written about the issue, but research on the subject is quite limited. Most of the trainers and coaches that claim loyalty to one of the positions base their opinion on empirical evidence, usually due to years of experience in the athletic training field.

The 1971 National Conference on the Medical Aspects of Sports, sponsored by the American Medical Association, once again brought the ankle taping issue to the attention of professional personnel in the related areas of sports medicine. Ferguson, professor of orthopedic surgery at the University of Pittsburgh and orthopedic consultant to the Pittsburgh Pirates, and Ryan presented papers with conflicting views as to the value of taping athletes' ankles to prevent knee injuries. Ryan[24] contended that ankle strappings protect the ankle from injury without endangering the knee. Conversely, Ferguson[25] asserted that ankle taping predisposes the knee to injury.

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[24]Opinion expressed by Allan J. Ryan in a paper presented to the American Medical Association's National Conference on Medical Aspects of Sports, New Orleans, Louisiana, November 28, 1971.

[25]Opinion expressed by Albert B. Ferguson, Jr., in a paper presented to the American Medical Association's National Conference on Medical Aspects of Sports, New Orleans, Louisiana, November 28, 1971.

Since fatigue is a predisposition to injury and knee strength depends upon the strength of the quadriceps and hamstrings, it was deemed worthwhile to investigate the effects of ankle taping upon the strength decrement of these muscle groups when subjected to stressful exercise. It is possible that ankle taping places a greater strain upon the quadriceps and hamstrings, thereby, hastening the onset of fatigue and predisposing the knee joint to injury. Such a study could lend credence to the ankle taping controversy and make an important contribution to the sparse amount of literature on the topic.

In the medical fields of endeavor which have utilized the measurement of skin temperature as a means for diagnosing certain diseases and medical conditions, there is general agreement that impaired body tissue appears "hotter" or "cooler" than normal tissue depending upon the type of impairment. This provided a basis for studying the effects of submaximal treadmill running upon the skin temperature change of selected thigh and knee joint locations and furthermore, to study the effect of ankle taping upon the temperature change.

Since skin temperature measurement has not been utilized as a diagnostic tool in sports medicine, it was considered worthwhile to provide some pertinent background information concerning the monitoring of skin temperature after stressful exercise involving the knee joint. Future researchers in this unexplored area could possibly utilize this information when designing their research studies.

DEFINITION OF TERMS

Isometric or Static Strength: The amount of force a muscle group can exert without shortening or lengthening. In this study, static strength was assessed in foot-pounds by the use of a torqueometer.

Knee Extensors: The quadriceps femoris muscle group which includes the rectus femoris, vastus lateralis, vastus intermedius, and vastus medialis muscles.

Knee Flexors: The sartorius, gracilis, popliteus, and gastrocnemius muscles, and the hamstring muscle group, including the biceps femoris, semitendinosus, and semimembranosus muscles.

Skin or Surface Temperature: The recording in degrees Centigrade of the radiant heat emitted from the skin.

Strength Decrement: The measurement in foot-pounds of the strength loss in a muscle group resulting from muscular exertion.

Submaximal Treadmill Running: Execution of a ten-minute treadmill run at a speed of six miles per hour and on a 10 per cent grade.

Taped Ankle: An ankle strapping that utilizes tape exclusively and not in combination with a cloth ankle wrap. In this study a modified Gibney technique with heel lock was used.

DELIMITATIONS OF THE STUDY

The subjects for the study were limited to sixty high school and college males. Fifty-one students from Louisiana State University and nine senior students from University Laboratory School, Baton Rouge, Louisiana, volunteered to participate in the study.

The exercise bout required in the study was limited to a ten-minute treadmill run on a 10 per cent grade at six miles per hour while the subject's ankles were taped and another run of the same magnitude with the ankles untaped. Only static strength was considered in the strength decrement measurement of the knee flexors and extensors. The strength measurements were obtained only at knee angles of 160 degrees for the knee flexors and 125 degrees for the knee extensors. The body surface locations which were checked for temperature change were limited to five selected areas of the thigh and knee joint.

The two testing sessions for each individual were spaced about one week apart. The time period for the complete study was six weeks.

LIMITATIONS OF THE STUDY

The motivational level of the subjects could have been a factor in the strength measurements although immediate reinforcement was given to the subjects by informing them of their strength score after each maximum exertion. Since the design of the study required the static strength assessment of two muscle groups, the pre and post-exercise strength testing was not uniform for each subject. This possibly could have affected the strength decrement measures. However, the order of strength testing for the knee flexors and extensors was systematically rotated throughout the study. This meant that under both experimental conditions (taped and untaped ankles), half of the sixty subjects were tested for knee flexor strength one minute after the treadmill run and the other thirty subjects assessed three to four minutes after exercise. The same rotational procedure was applied in testing static strength of the knee extensors except the right and left extensors were assessed separately. The right leg was always tested first.

Because of the number of factors which can affect the temperature of the skin, the environmental conditions for skin temperature measurements possibly produced some limitations. An effort was made, however, to minimize the negative effect of artifacts by controlling the ambient room temperature, maintaining constant room conditions, urging subjects not to smoke or eat for at least three hours before testing, and requesting that each subject dress only in gym shorts, tennis shoes, and socks. The investigator could not control such factors as emotions, sleep, and amount of physical activity on the day of testing.

It has been reported in the literature that a subject should not eat or drink for approximately twelve hours before participating in a study involving the measurement of skin temperature. Since this study required each subject to complete a strenuous treadmill run, it was not feasible to request the subject to refrain from food intake for a time period of such length.

CHAPTER II

REVIEW OF RELATED LITERATURE

INTRODUCTION

Since this study was concerned with the measurement of isometric strength and skin temperature, a review of pertinent literature was conducted in order to select reliable measuring devices, proper joint angles for the strength measurements, and befitting environmental conditions for the recording of skin temperature.

The first section of the chapter provides some basic information concerning the measurement of static strength and skin temperature. The second section includes studies that were concerned with various aspects of preventive ankle taping followed by a review of studies that involved the use of strength decrement as a criterion for fatigue following strenuous muscular activity. The next section summarized some research studies which included the measurement of skin temperature for physiological or pathological purposes. The concluding section includes a summary of the related literature.

Static Strength Measurement

Although the cable tensiometer is possibly used most often in static strength measurement, other devices are commonly mentioned in the literature. Such instruments as the strain gauge, the spring scale, hand and leg dynamometers, the manuometer, and the myometer have been used in physical education research.

Drury and Broussard, who were instrumental in popularizing isometric exercises for athletic training in the late 1950's,[1] developed a torque table which has proven to be of considerable value in measuring isometric strength. The instrument is designed to measure the amount of force exerted by the muscles of the arms and legs. The instrument uniquely features arm and leg levers adjustable in length and angle of pull. The table has been used in the athletic training room at Louisiana State University and is reported to be very reliable and convenient in measuring and developing the strength of the arms and legs.[2] Bergeron[3] used the torque table in a study which compared the effectiveness of systematic weight training and isometric exercise for the production of strength and muscle girth. The static strength device was employed by Sterling[4] in a study designed to compare the position selectivity of strength gains in the elbow flexor, knee flexor, and knee extensor muscle groups. Sterling reported reliability coefficients ranging from a low of .78 in 170 degree knee extension to a high of .98 in 95 degree knee extension.

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[1]Charles A. Bucher, Foundations of Physical Education (St. Louis: The C. V. Mosby Company, 1968), pp. 475-477.

[2]Francis A. Drury, "The Torque Table" (Louisiana State University, 1960), p. 1. (Mimeographed).

[3]Philip C. Bergeron, Jr., "A Comparison of the Effectiveness of Systematic Weight Training and Isometric Exercise in the Development of Strength and Muscle Girth" (unpublished Master's thesis, Louisiana State University, Baton Rouge, 1963), pp. 26-27.

[4]Duane Ray Sterling, "A Comparative Study of the Position Selectivity of Isometric Strength Changes Resulting from Isometric Exercise" (unpublished Master's thesis, Louisiana State University, Baton Rouge, 1964), p. 36.

Campney and Wehr,[5] utilizing cable-tension tests, measured the strength of forty-two subjects at ten-degree intervals for thirteen joint angles (60 degrees to 180 degrees) for shoulder flexion and nine joint angles (80 degrees to 160 degrees) for knee extension. Each test was repeated until the strength scores stabilized at each angle. They concluded that the joint angles for knee extension (140 degrees, 150 degrees, and 160 degrees) indicated significantly less strength values than the strength observed at any joint angle between 80 degrees and 120 degrees.

Clarke et al.,[6] determined leg extension strength at various angles by using a tensiometer to record the force of extension. The subjects were instructed to sit on the end of a table while leaning backward with the arms extended to the rear and the hands holding the sides of the table. The greatest amount of force was applied at leg angles between 105 and 124 degrees.

Berger[7] conducted a study to determine the differences in the amount of force that could be exerted at leg angles of approximately 105 degrees, 120 degrees, and 140 degrees. The inverted leg press was used as the body position for testing. Strength scores increased from leg

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[5]Harry K. Campney and Richard W. Wehr, "An Interpretation of the Strength Differences Associated with Varying Angles of Pull," The Research Quarterly, XXXVI (December, 1965), 411.

[6]H. Harrison Clarke, Clayton T. Shay, and Donald K. Mathews, "Relationship between Body Position and the Application of Muscle Power to Movement of the Joints," Archives of Physical Medicine and Rehabilitation, XXXI (1950), 89.

[7]Richard A. Berger, "Leg Extension Force at Three Different Angles," The Research Quarterly, XXXVII (December, 1966), 560-562.

angles of 105 degrees to 140 degrees. These results were in contradiction to Clarke's findings, but the author concluded that the differences were probably due to the differences in the body position of the subjects. Berger further surmised that the body position used in his study resulted in the gluteus maximus aiding in knee extension.

In studying knee flexion with the use of a cable tensiometer, Clarke[8] found that knee flexion strength leveled off between 145 degrees and 180 degrees. The greatest mean strength was observed at an angle of 165 degrees. The subjects were in a prone position with the lower legs extended beyond the end of a table, and the arms were folded in front of the head.

Skin Temperature Measurement

In addition to the selection of proper knee joint angles and a reliable strength measurement instrument for employment in the strength measurement phase of this study, the author surveyed the literature concerning skin temperature measurement in order that sufficient environmental conditions could be ascertained as well as the selection of a reliable instrument for measuring body surface temperature.

There has been some reluctance by experts in various fields to accept the measurement of skin temperature for clinical use. This is chiefly due to the propensity of the skin to fluctuate widely because of a number of influential factors. Notwithstanding the factors that cause

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[8] H. Harrison Clarke, Muscular Strength and Endurance in Man (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1966), pp. 40-41.

the skin temperature to vary, Mali,[9] Allen and Barker[10] have declared that the measurement of skin temperature has its greatest value when differences in the temperature of two sides of the body are demonstrated. It is felt that regardless of the factors that influence this variability, bilateral symmetry of opposite body parts should be evident or there is reason to suspect an impairment in one of the assumed counterparts. Barnes[11] and Williams[12] stated that infrared heat instruments are capable of measuring the skin temperature reliably and with sufficient accuracy, but to be of diagnostic value, the researcher must insure that the measured temperatures are reflected by the physiological or pathological condition of the body and not caused by artifacts. There is general agreement that clothing should be removed, a suitable waiting period provided in a draft-free room with an ambient room temperature of 65 degrees to 75 degrees Fahrenheit void of objects of either high or low temperatures, and a consistent body positioning of the subject.

Allen and Barker[13] suggested that humidity of the surrounding air has almost no influence on the temperature of the skin. These

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[9]J. W. H. Mali, "Some Physiological Aspects of the Temperature of the Body Surface," Medical Thermography-Proceedings of a Boerhaave Course for Postgraduate Medical Education, 1969, pp. 8-21.

[10]Edgar Allen and Hines Barker, Peripheral Vascular Disease (Philadelphia: W. B. Saunders Company, 1947), p. 104.

[11]R. Bowling Barnes, "Thermography," Annals of the New York Academy of Sciences, CXXI (October, 1964), 45.

[12]Lloyd F. Williams, K. Lloyd Williams, and R. S. Handley, "Infrared Thermometer in the Diagnosis of Breast Disease," Lancet, II (1961), 1378.

[13]Allen and Barker, op. cit., p. 142.

investigators also claimed that the skin temperature value can be determined only if the patient is in a room with a constant temperature, only if he has refrained from the ingestion of foods for approximately twelve hours prior to the tests, only if he has not smoked within a period of two or three hours, only if the subject is free from emotional distress, and only if the skin has been exposed to a stabilization period of one to two hours. It is not uncommon, however, to find in the literature a recommended stabilization period of only ten to fifteen minutes.[14, 15] Under these conditions the skin temperature is relatively constant for the same person.

During the last thirty years, many infrared detection devices have been developed, particularly in the United States, Great Britain, and Russia. The infrared radiation instruments are used extensively in industry and science, but only in the last ten years has it occurred to isolated observers that such apparatus might make a useful contribution to the field of medicine.

Many instruments are available for measuring infrared emission, but the thermograph and infrared thermometer are the most sophisticated infrared energy devices for clinical use. The first instrument for discussion is the thermograph which provides in pictorial form a quantitative thermal map of relatively large areas of the skin. The infrared radiation is focused upon a sensitive thermistor and compared 200 times per second with the energy being emitted by an ambient controlled

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[14]J. Gershon-Cohen, Jo Ann D. Haberman-Brueschke, and Erich E. Brueschke, "Medical Thermography: A Summary of Current Status," The Radiologic Clinics of North America, III (December, 1965), 411.

[15]Barnes, loc. cit.

temperature reference. Scanning of large body surfaces can be completed in approximately three minutes. The film of the scanned area (thermogram) is available for study ten seconds after the scan is completed. The final product is a quantitative two-dimensional thermal map of the patient's skin temperature. The hot areas are portrayed in light shades and the cool areas in darker tones. Ten temperature blocks of known value are imprinted upon each thermogram forming a "thermal-gray scale" for comparison. It is very difficult to grade the scale with the naked eye; therefore, electronic equipment has been devised to interpret the films densitometrically.[16] If the sophisticated electronic equipment is not available, a serious handicap is placed on the use of the thermograph, because in this situation the device has limited value for statistical analysis.

An infrared thermometer (radiometer) has some distinct advantages over many of the other infrared detection devices. The portable instrument requires only one second per measurement and the calibration is accurate to about $\pm$ 0.1 degree Centigrade. An aluminum cone is attached in front of a germanium lens and eliminates any infrared radiation which could strike the lens from the side and scatter onto the thermistor bolometer or heat detector. The cone also assists the operator by serving as an aiming device. Some types of radiometers employ a pistol-grip handle to aid the user in accuracy and consistency of measurement. The radiometer is especially valuable for screening large numbers of people and most expedient when scanning a large number of

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[16]Gershon-Cohen, et al., op. cit., pp. 403-431.

precise body landmarks on one person. The infrared thermometer is most useful in research studies because the radiant temperature values can be treated statistically.

STUDIES CONCERNED WITH PREVENTIVE ANKLE TAPING

A survey of the literature concerned with ankle taping substantiated the fact that the Gibney technique (basket weave) was the most commonly used and best fitted method for preventive ankle taping. Today there are numerous variations from the original Gibney method.

An investigation by Rarick et al.,[17] was designed to compare the measurable support provided by four different methods of ankle taping before and after exercise. The conventional methods of ankle taping selected for study were: (1) the basket weave, (2) the basket weave and stirrup, (3) the basket weave and heel lock, and (4) the basket weave with combination stirrup and heel lock. A special device was developed by the investigators which enabled them to measure the resistance and the range of movement provided by each ankle strapping as the subject's foot was passively moved in plantar flexion and inversion. This movement simulates the movement involved in the majority of ankle sprains, and it is also the movement which conventional ankle taping techniques are designed to restrict. A standardized ten-minute exercise program of running, jumping, pivoting, quick starts, and quick stops was employed to place the ankles under stress. Force and range of

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[17]G. Lawrence Rarick and others, "The Measurable Support of the Ankle Joint by Conventional Methods of Taping," Journal of Bone and Joint Surgery, XLIV (September, 1962), 1190.

movement values were recorded after the exercise period. A cable tensiometer and range of motion indicator were used to obtain the force and range of motion data.

In general, all of the methods of ankle taping lost about 40 per cent of holding power during the exercise period as indicated by the differences of pre and post-exercise force readings. The results of the study indicated that the greatest support was provided by the basket weave with the combination stirrup and heel lock. The support of the basket weave with the stirrup was almost as great. The least supporting strength was found in the basic basket weave method both before and after exercise. The researchers further concluded that although some support is given to the ankle joint by current methods of taping, there is some question about the amount of protection. Because the tape loosened during exercise and lost approximately 40 per cent of its supporting strength, the researchers conjectured that ankle protection by these methods was less than originally believed.

Robien[18] conducted a study which compared three types of preventive ankle taping. The techniques included the Gibney method with one-inch tape, the Gibney method with one and one-half inch tape, and the wrap-around with one and one-half inch tape. Twenty subjects were tested for the range of motion of their untaped ankles and the range of motion with the above types of taping applied to the ankles. A gonimeter was used to measure the range of motion at the ankle joint in

[18]Gerhard Carl Robien, Jr., "A Study of Three Types of Preventive Ankle Taping" (microcarded Master's thesis, University of Wisconsin, Madison, 1954), pp. 46-47.

eversion, inversion, and flexion-extension. The Gibney technique with one-inch tape was determined the most restrictive in eversion and inversion but only second best in not restricting flexion-extension of the foot and ankle. The Gibney or basket weave strapping with one and one-half inch tape ranked next to the Gibney wrap with one-inch tape in eversion and inversion but was superior in not restricting flexion-extension of the foot and ankle. The wrap-around technique was least restrictive to eversion and inversion and the most restrictive to the flexion-extension of the ankle and foot; therefore, this method was judged the least beneficial of the three preventive ankle taping methods.

The support given to the ankle joint by four conventional methods of ankle taping was studied by Simpson.[19] The taping methods included the standard basket weave with superimposed stirrup, the standard basket weave with the superimposed heel lock, and the standard basket weave with stirrup and heel lock superimposed. Force and range of motion data were obtained with and without the use of the taping methods. The support of the taping methods was measured before and after a one-minute standard amount of exercise which included running, jumping, sprinting starts, quick stops and starts. The equipment was designed to simulate the ankle movement associated with plantar flexion and medial rotation. This was accomplished by a cable threaded through a pulley. The subject's right foot was placed in a size ten and one-half football shoe (all subjects had shoe size of ten and one-half) which had an eye screw mounted on the sole of the shoe near the toe. This served as an

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[19]Ben J. Simpson, "The Measurable Support Given to the Ankle Joint by Conventional Methods of Ankle Taping" (microcarded Master's thesis, Kansas State Teacher's College, Emporia, 1966), pp. 27-51.

anchor point for the cable through which tension was applied to the foot by a manual lever system. A measuring board graduated in one-half inch units permitted accurate measurement of the distance a marker moved on the cable.

The basket weave with stirrup and heel lock displayed a greater strength retention for both the exercised and unexercised condition. Loss of adherence, stretching, and some tearing of the tape were observed after exercise for all the methods of ankle taping. The effect of exercise reduced the support provided by the tape throughout the ankle's normal range of movement.

Gualtiere[20] studied the effect of the figure-eight ankle wrap bandage on performance in selected basketball skills. One hundred male university students were tested for speed, vertical jumping ability, and agility with and without the figure-eight ankle wrap. The figure-eight wrap restricted vertical jumping, had no effect on running speed, and improved agility.

McCorkle[21] used electrogoniometer measurements to study the effects of adhesive strapping techniques on ankle flexion-extension. The Johnson & Johnson Tape Cast, the Lonn-Mann Taping Technique, and the Springfield Modified Tape Technique were the strapping methods utilized in the study. The taping techniques reduced ankle

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[20]William Gualtiere, "A Study of the Effect of the Figure-Eight Ankle Wrap Bandage on Performance in Selected Basketball Skills (unpublished Master's thesis, Ohio University, Athens, 1961), pp. 44-45.

[21]Richard B. McCorkle, "A Study of the Effect of Adhesive Strapping Techniques on Ankle Action" (unpublished Master's thesis, Springfield College, Springfield, Massachusetts, 1963), pp. 71-75.

flexion-extension 6.4 degrees or approximately 6 per cent. However, when skillfully strapped, the restriction did not affect agility run times of eighteen male college students.

In studying the effects of ankle taping on motor performance, Mayhew[22] administered the Illinois Agility Run, fifty-yard dash, vertical jump, and standing broad jump to sixty-six subjects. Following a counterbalanced testing order, the tests were conducted with the subjects' ankles both taped and untaped. The standard closed Gibney strapping significantly impaired the vertical jump and the standing broad jump. The ankle taping did not affect the agility run times, but the fifty-yard dash showed a trend toward impaired performance. The author concluded that the standard closed Gibney ankle strapping impaired performance in the activities that were greatly dependent upon plantar flexion of the feet.

Simon[23] compared the effectiveness of ankle taping and ankle wrapping in preventing ankle injuries and found no evidence to support or reject either taping or wrapping as a means to prevent ankle injuries. The investigator divided a college football squad into two groups for the spring practice periods of two consecutive years. In 1967, one group's ankles were wrapped daily with the "Louisiana Wrap," while the members of the other group were taped with double figure-eights, medial

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[22] J. L. Mayhew, "Effects of Ankle Taping on Motor Performance," Journal of the National Athletic Trainers Association, VIII (March, 1972), pp. 10-11.

[23] James E. Simon, "Study of Comparative Effectiveness of Ankle Taping and Ankle Wrapping in the Prevention of Ankle Injuries," Journal of the National Athletic Trainers Association, IV (Summer, 1969), pp. 6-7.

and lateral heel locks, and double stirrups. The procedure was repeated in 1968 with the two groups reversed as to the type of ankle support applied. Only four ankle injuries were sustained under each condition of ankle support.

Wells[24] surveyed twenty colleges and universities from three major conferences to study the incidence of knee injuries in relation to ankle taping. The number of knee injuries sustained, whether or not the ankle was taped, and the requirements for ankle taping were obtained. Although no general indication of a marked increase in knee injuries due to ankle taping was noted, the author implied that under certain predisposing conditions, the taped ankle may be one of the causes of knee injuries.

Stretch,[25] in a survey study involving 516 high schools in Michigan, used chi-square analysis in finding no relationship between the incidence of knee injuries and the use of adhesive and cloth ankle wrappings.

In a letter to the author, Ferguson,[26] professor of orthopedic surgery at the University of Pittsburgh, cited a study by the New York State Public High School Athletic Association which involved 61,000 instances in which either ankle support or no ankle support was used.

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[24]John Charles Wells, "The Incidence of Knee Injuries in Relation to Ankle Taping," <u>Journal of the National Athletic Trainers Association</u>, IV (Winter, 1969), pp. 10-13.

[25]Clyde J. Stretch, "The Relationship Between Ankle-Taping and Knee Injuries in High School Football" (unpublished Master's thesis, Michigan State University, Lansing, 1966), pp. 12-25.

[26]Statement by Albert B. Ferguson, Jr., in a letter to the author, December 8, 1971.

The orthopedic consultant to the Pittsburgh Pirates stated that a decreased incidence of knee injuries was shown when the ankles were not supported.

STUDIES CONCERNED WITH STRENGTH DECREMENT FOLLOWING EXERCISE

The strength decrement studies surveyed included studies that involved the lower extremities.

The phenomenon of fatigue has intrigued researchers in psychology and physical education for some time. Strength decrement, not as complex or difficult to study as some of the other indices for fatigue, has been researched chiefly with the use of the cable tensiometer when only the lower extremities have been involved.

Clarke,[27] one of the first researchers to study strength decrement following exercise, analyzed the strength decrement fatigue effects in fourteen muscle groups of the trunk and lower extremities. Seventeen subjects were subjected to a submaximal treadmill run at seven miles per hour for a period of ten minutes on a horizontal plane. Only two muscle groups, the hip outward rotators and the trunk flexors, were fatigued sufficiently to cause a significant decrement. The knee flexors had a mean strength loss which approached but did not reach the .05 level of confidence.

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[27]H. Harrison Clarke, "Strength Decrement of Muscles of Trunk and Lower Extremities from Sub-Maximal Treadmill Running," The Research Quarterly, XXVIII (May, 1957), 95-99.

Clarke[28] investigated the strength loss effects on four muscle groups of the lower leg and ankle resulting from wearing three types of army boots and shoes on a standardized pack-carrying march. The combat boot, a rubber insulated boot, and a quarter-cut shoe were used as the subjects completed three marches, wearing a different boot or shoe each march. Twenty-nine college students marched 7.5 miles at 2.5 miles per hour. A combat pack was carried on all marches along with the equipment used by a combat rifleman. The total weight of the load was forty-one pounds.

The marches with the combat boot resulted in the least strength loss of the lower leg muscles and ankle with the largest decrement of strength being found when the subjects were wearing quarter-cut shoes. The muscle group most affected by proportionate strength losses for the three footwear marches was the ankle everter. The ankle plantar flexors, the ankle inverters, and the ankle dorsi flexors followed in order of highest to lowest strength decrement.

In another study by Clarke and associates,[29] the strength decrement of muscles primarily involved in carrying army packs on military marches was determined. Nine different seven and one-half mile marches were conducted with the weight load and distribution varying from march to march. The rate of each march was 2.5 miles in fifty minutes. The

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[28] H. Harrison Clarke, "Strength Decrements from Wearing Various Army Boots and Shoes on Military Marches," The Research Quarterly, XXVI (October, 1955), 266-272.

[29] H. Harrison Clarke, Clayton T. Shay, and Donald K. Mathews, "Strength Decrements from Carrying Various Army Packs on Military Marches," The Research Quarterly, XXVI (October, 1955), 253-265.

muscle groups with the greatest strength losses for the nine marches were the trunk extensors in eight marches, the hip extensors in seven marches, and the knee flexors in six marches. The knee extensors had the least mean strength losses of the eight muscle groups.

In an investigation involving the strength decrement of selected muscle groups which resulted from treadmill walking at different grades while back-packing a prescribed load, Thiele[30] subjected ten male subjects to a thirty-minute walk on a horizontal plane, at a 5 per cent and a 10 per cent grade. The subject carried a sixty-two pound pack during each walk. In testing the strength decrement of the shoulder flexors, trunk flexors, hip flexors, hip extensors, knee flexors, and the knee extensors, all muscle groups displayed significant decrements. When the elevation was increased from one level to another, only the shoulder flexors and the knee extensors revealed a significant increase in decrement. The significant decrement was evident when changing from a horizontal plane to a 5 per cent grade but not shown when elevated from a 5 to 10 per cent grade.

Davis[31] employed a timed 200-yard swim as an exercise bout in order to study the strength decrement of the muscle groups involved with

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[30]Barton A. Thiele, "A Study to Investigate the Strength Decrement of Selected Muscle Groups During Treadmill Walking at Different Grade Levels While Back-Packing A Prescribed Load," (unpublished Master's thesis, Montana State University, Missoula, 1963), pp. 25-29.

[31]Jack F. Davis, "Effects of Training and Conditioning for Middle Distance Swimming upon Measures of Cardiovascular Condition, General Body Fitness, Gross Strength, Motor Fitness and Strength of Involved Muscles" (microcarded doctoral dissertation, University of Oregon, Eugene, 1955), pp. 73-89.

shoulder flexion and extension, hip flexion and extension, and knee flexion and extension. Two swim trials were required; one with the subjects in an unconditioned state, and the final trial was experienced after five weeks of training. Although the subjects improved their time on the second trial, the strength decrement for the two trials was nonsignificant.

STUDIES CONCERNED WITH THE MEASUREMENT OF SKIN TEMPERATURE

Hardy[32] emphasized the advantages of using infrared radiometers for the measurement of skin temperature nearly forty years ago, but only in the last ten years has the potential tool for medical diagnosis received much attention. The measurement of skin temperature with these instruments is evident to some extent today in related fields of science and medicine. There is general agreement that as of yet, the chief value of using skin temperature measurement for diagnostic purposes is in the comparison of paired body parts. Most skin temperature studies have been conducted during the resting state of the body and not during an exercise period; consequently, the skin temperature research in physical education is extremely limited. As a result, the majority of the studies reviewed were studies conducted in various fields of medicine.

Winslow et al.,[33] completed an experiment on a muscular and a slender young man to decide the height of skin temperature and heat loss

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[32] J. D. Hardy, "Radiation of Heat from Human Body: Human Skin as Blackbody Radiator," Journal of Clinical Investigation, XIII (1934), 615.

[33] L. E. A. Winslow, L. P. Herrington, and A. P. Gagge, "Body Reactions to Environmental Temperature," American Journal of Physiology, XXX (1937), 9.

under certain experimental conditions. The subjects were seated nude in a laboratory room chair with the basal metabolism measured for production of heat, and the body's heat loss was measured by radiation, conduction, convection, and evaporation. There was a consistency in the metabolism within an environmental temperature range of 18 to 42 degrees Centigrade; the loss of heat by radiation, conduction, and convection was in proportion to the temperature of the environment. It was noted that the loss of heat by radiation decreased when the environmental temperature increased; this was due to the onset of sweating. When the subjects were not sweating, the heat loss by radiation comprised better than 50 per cent of the heat loss.

Barnes[34] reported that when ambient room temperatures are static, objects obtain thermal equilibrium with their skin temperature being determined by heat flow to the surface and heat losses from the surface. The heat flow to the skin is governed largely by local vascularities and metabolism while evaporation, convection, conduction, and infrared radiation emission cause the heat loss. This statement is in agreement with many researchers involved with skin temperature measurement.

van der Staak[35] used a modified heated thermocouple system to illustrate the above principle concerning the origin of skin temperature. The conduction of internal heat from the body through the tissues and the

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[34] R. Bowling Barnes, "Determination of Body Temperature by Infrared Emission," Journal of Applied Physiology, XII (June, 1967), 1143-1146.

[35] W. J. B. M. van der Staak, "Experiences with the Heated Thermocouple," Dermatologica, CXXXII (1966), 192-205.

convection of heat by means of the blood flow were confirmed as the functions which reflect skin temperature.

The equilibrium temperature of skin usually falls somewhere between 29 and 35 degrees Centigrade within a room held at 23 degrees Centigrade and free from air currents. Barnes,[36] using an infrared thermometer (radiometer), measured eight body areas, including five body cavities, in a room with a temperature of 23 degrees Centigrade. It was found that the deeper the cavities, the closer the temperature was to the core temperature of the body. The surface temperature of the external auditory canal wall approached the oral body temperature. Subjects who exhibited deep and concave navels revealed skin temperatures which approached the ear canal temperatures. The temperatures of the nostrils and the open mouth were affected by air convections and heat losses due to evaporation. The temperatures of the surface of the eye, the forehead, and the palm of the hand were affected by radiation and evaporation. Of the flat body surfaces tested, the forehead revealed the highest temperature while the palm had the lowest temperature and the widest fluctuation.

Baker and Taylor[37] contradicted the usual assumption that emotional stress produces a constriction of the arterioles and thus causes a reduction in skin temperature. The researchers conducted a study

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[36]Barnes, "Determination of Body Temperature by Infrared Emission," loc. cit.

[37]Lawrence M. Baker and William M. Taylor, "The Relationship Under Stress Between Changes in Skin Temperature, Electrical Skin Resistance, and Pulse Rate," Journal of Experimental Psychology, XLVIII (May, 1954), 361-366.

whereby polygraph recordings of skin temperature, skin resistance, and the pulse were made of fifty-two subjects exposed to an emotion-provoking condition. The imposed stress stimuli included the use of electrical sparks via an electric coil and an optimal level of induced muscular tension with the use of a hand dynamometer. Skin temperature changes increased significantly when both spark and tension stimulation were involved. The authors inferred that skin temperature measurement may be a promising index for emotional reactivity, and may find uses similar to the galvanic skin response and blood pressure.

In the past, rheumatologists attempted to quantitate inflammation with the use of thermocouples; however, this procedure was proved inadequate because of the frequent production of artifacts. The use of infrared heat detection as a possible method for diagnosis of rheumatoid arthritis has been studied by Boas[38] with the use of thermography.

Twenty-seven patients with active rheumatoid arthritis and ten normal individuals were selected for thermography study. A ten-minute pre-test period was utilized to permit the skin temperature of the unclothed subjects to stabilize with the ambient room temperature.

A Barnes Infrared Thermograph was utilized for the heat scanning process. Polaroid film was utilized to produce the thermal images of the body surface (thermograms). The scans required five to twelve minutes depending upon the completeness of the scan. To determine

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[38]Norman F. Boas, "Thermography in Rheumatoid Arthritis," Annals of the New York Academy of Sciences, CXXI (October, 1964), 223-234.

the patient's skin temperature for the particular area under study, the Barnes Portable Medical Thermometer was used.

Bilateral asymmetry of skin temperature in paired body parts was evident in many of the subjects. This information reflected the value of the use of thermography in diagnostic work. The author, however, cited one drawback to the procedure; since most patients with rheumatoid polyarthritis are affected on both sides of the body, this creates difficulty in obtaining normal thermal reference points to express the changes in skin temperature.

The use of thermography has spread to the fields of obstetrics and gynecology as evidenced by recent studies. One such use is to locate the placenta because this body site is warmer than surrounding tissues and liberates heat which is conducted to the abdominal surface. At Albert Einstein Medical Center in Philadelphia, this practice correctly located the placenta in forty-eight of fifty-four cases. This is important because with thermography there is complete maternal and fetal safety, as opposed to the use of roentgenography and radioactive isotopes which are disadvantaged by the radiation hazard. Pregnancy can be detected two weeks after conception provided a pre-conception thermogram is available for comparison. The rise in skin temperature increases linearly with the time of pregnancy. When ingested, oral contraceptives produce heat patterns observed in pregnancy.[39]

Thermography has also been utilized in the detection of breast cancer. From a total of 100 detected breast cancers, the sole clue

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[39]Gershon-Cohen, Haberman-Brueschke and Brueschke, op. cit., pp. 413-419.

in seven cases was a thermograph detection of a "hot spot" in the affected breast. Gershon-Cohen and associates[40] have implemented medical thermography in the detection of various other diseases; namely, fibroadenoma, secretory disease, mazoplasia cystica, and other non-malignant conditions.

Thermography has been valuable in identifying metastic lesions that were elusive to roentgenography and isotope studies. This practice has been so successful that therapy is instituted immediately if the thermographic findings are positive. The progress of the cancer therapy can be evaluated by thermography because of the return to normalcy in skin temperature if therapy is successful.

Albert et al.,[41] found thermography to be useful in the diagnosis of orthopedic problems. Such infirmities as herniated discs, fractures, sprains, and contusions have been studied. The skin over fracture sites has been observed to remain hot long after the apparent healing of the bone. One documented case of a chronic ankle sprain showed that positive thermographic findings persisted for nine months, and a patient with synovitis of the right knee demonstrated a constant elevation of overlying skin temperature.

Some researchers indicate that thermography shows bright promise in the detection of peripheral vascular disease. Thrombophlebitis,

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[40] J. Gershon-Cohen and others, "Advances in Thermography and Mammography," Annals of The New York Academy of Sciences, CXXI (1964), 283-300.

[41] S. M. Albert, M. Glickman, and M. Kallish, "Thermography in Orthopedics," Annals of The New York Academy of Sciences, CXXI (October, 1964), 157-170.

varicose veins, arteriosclerosis, Buerger's, and Raynaud's diseases can be detected by thermography. Strokes and other cerebrovascular disease have also been detected by the use of thermography.[42]

The medical specialty of dermatology has instituted thermography in the diagnosis and prognosis of frostbite injuries and in the treatment of burns.[43]

Apparently, there is some validity to the comparison of thermograms to fingerprints because repeated thermograms on the same person show duplicate thermal patterns unless some significant change has occurred in the subject. In studying the effect of local isometric muscular activity on skin temperature, O'Connell[44] discovered that this type exercise caused a significant increase in skin temperature. Twenty-four subjects performed thirty maximal contractions with the right forearm flexor muscles in a one-minute time period on two separate occasions. The left arm acted as a control for both experiments. The surface skin temperature recordings, obtained with a Clark and Trolander thermistor thermometer, were taken over the belly of the biceps muscle. The skin temperature measurements were recorded immediately before exercise, and after three minutes of post-exercise rest. Both arms increased in temperature with the exercised arm showing a significantly higher mean temperature than the left arm in both experiments.

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[42]Gershon-Cohen and others, "Medical Thermography: A Summary of Current Status," op. cit., p. 422.

[43]Albert, Glickman, and Kallish, loc. cit.

[44]Eugene R. O'Connell, "The Effect of Local Isometric Muscular Activity on Local Skin Temperature," Journal of the Association for Physical and Mental Rehabilitation, XIV (May-June, 1960), 74-75.

Loiselle[45] used a bicycle ergometer in testing twelve subjects under varied temperature, humidity, and workload conditions to determine these effects on fitness test performance. One of the physiological parameters studied was skin temperature. The average surface temperature from six points on the skin was compared to the skin temperature of the exercising muscle group, the quadriceps femoris. The temperature readings were obtained between the fifth and sixth minutes of exercise by the use of copper constantan thermocouples. The investigator discovered that the surface temperature over the exercising muscle group was lower than the average of the other muscle groups. The skin temperature increased with increased humidity and increased even higher under both high temperature and high humidity conditions. Post-exercise temperature was not recorded in this study.

Eckerson[46] investigated the changes in selected physiological parameters of eight lightly clothed male subjects while they pedaled a bicycle ergometer and were exposed transiently to varying degrees of low ambient temperature. One of the selected parameters was skin temperature. Ambient temperatures of 20 degrees, 10 degrees, 0 degrees, -10 degrees, -20 degrees, and -30 degrees Centigrade were utilized. Skin temperatures were measured before, during, and after the periods of pedaling.

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[45]Dennis Loiselle, "The Effects of Varied Thermal Environments on Selected Physiological Variables," (microcarded Master's thesis, University of Alberta, Edmonton, 1966), pp. 14-54.

[46]John Donald Eckerson, "Changes in Selected Physiological Parameters as a Function of Low Ambient Temperature," (microcarded doctoral dissertation, University of Oregon, Eugene, 1967), pp. 93-98.

The mean skin temperature of the subjects, recorded with the use of thermocouples, declined during the period of pedaling in all the ambient temperatures except during the exposure to -20 degrees Centigrade. The rate and extent of the decline appeared to be directly related to the lowering of the ambient temperature.

Apple[47] studied the residual effects of stressful treadmill running on the skin temperature measurements of the sole of the feet by subjecting ten subjects to a five-minute run at six miles per hour and a 10 per cent grade on successive days. The exercise task of the first day significantly affected the pre-exercise skin temperature on the second day. The investigator also found a significant relationship of right and left feet concerning skin temperature increase in four selected foot stress areas. Collins[48] studied the symmetry of foot surface temperature and found a highly significant relationship in the skin temperature of six selected weight-bearing areas of the feet after exposure to exercise. In this study, thirty subjects were subjected to a ten-minute treadmill walk at 3.5 miles per hour and a 10 per cent incline.

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[47] John F. Apple, "The Summating Effect of Stressful Treadmill Running on the Heat Measurements of the Sole of The Foot" (unpublished Master's thesis, Louisiana State University, Baton Rouge, 1971), pp. 48-50.

[48] D. Ray Collins, "A Comparison of the 'Slipper-Sock' Footprint Test and the Harris Footprint Test as Possible Indices for Prediction of Skin Temperature Change of the Feet" (paper read at the Social and Rehabilitation Service General Research Meeting at the U. S. Public Health Service Hospital, Carville, Louisiana, April 13, 1971).

There is evidence in the literature that thermocouples have received considerable criticism as instruments for measuring skin temperature. Other infrared detection devices, such as the infrared thermometer (radiometer), reportedly have greater reliability. The calibration of the Barnes MT-3 Infrared Thermometer, for example, has reported to be accurate to about ±0.1 degree Centigrade.[49]

SUMMARY OF RELATED LITERATURE

The first section contained some basic information regarding static strength and skin temperature measurement. The second section of this chapter was concerned with studies related to preventive ankle taping. Four studies that were reviewed compared conventional methods of ankle taping on the criterion of support given to the ankle.[50] Two studies found the basket weave with combination stirrup and heel lock as being most effective in adding support to the ankles during physical activity.[51] In another study the basket weave or Gibney method with one-inch tape was judged most effective in restricting movement of inversion and eversion.[52] One study indicated that ankle strapping reduced ankle flexion-extension but that the restriction did not affect agility run times.[53]

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[49] Barnes, "Determination of Body Temperature by Infrared Emission," op. cit., p. 1143.

[50] Rarick and others; Robien; Simpson; McCorkle; loc. cit.

[51] Rarick and others; Simpson; loc. cit.

[52] Robien, loc. cit.

[53] Mayhew, loc. cit.

One study revealed that the figure-eight ankle wrap had no effect on running speed, restricted vertical jumping ability, and improved agility.[54] Another study indicated that the closed standard Gibney ankle strapping impaired performances in the vertical jump and standing broad jump, contributed to a trend of impaired performance in the fifty-yard dash, and did not affect agility run times.[55] One study found no difference between ankle taping and ankle wrapping as means to prevent ankle injuries.[56] One study was cited which concluded that non-ankle support during athletic competition decreased the incidence of knee injuries.[57]

Two survey studies were reviewed that were designed to determine the incidence of knee injuries in relation to ankle taping.[58] No relationship was found between the incidence of knee injuries and the use of ankle strappings in either study.

The third section included some studies that were concerned with strength decrement following exercise. These studies were limited to investigations which involved the measurement of strength decrement in the lower extremities. One study utilized a ten-minute treadmill run at seven miles per hour and a horizontal plane.[59] Two studies employed a 7.5 military march as the exercise task.[60] Another study

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[54]Gualtiere, loc. cit. [55]Mayhew, loc. cit.

[56]Simon, loc. cit. [57]Ferguson, loc. cit.

[58]Stretch; Wells; loc. cit. [59]Clarke, loc. cit.

[60]Clarke, Shay, and Mathews, loc. cit.

required a thirty-minute treadmill walk at three different grades while the subject back-packed a prescribed load.[61] A timed 200-yard swim was used by one investigator to produce a strength decrement in certain muscle groups.[62] In the study involving the treadmill run, strength decrement was significant in the hip outward rotators and the trunk flexors.[63] None of the muscle groups of the lower extremities displayed significant strength loss, but the knee flexors strength loss approached significance at the .05 level of probability. The ankle everters showed the greatest strength loss in the study involving types of shoe wear in military marches.[64] The other study that used the military march under various conditions of pack-carrying, illustrated a greater strength loss in the trunk extensors.[65] In the study involving a thirty-minute treadmill walk with subjects back-packing a designated load, all muscle groups tested showed a significant decrement.[66] One study found an insignificant strength decrement index for 200-yard swim trials which were conducted before and after a five-week training period.[67]

The next section of this chapter reviewed some studies pertinent to the measurement of skin temperature. A total of fifteen studies were cited. One study concluded that sweating caused a decrease in the loss of heat by radiation as the environmental temperature increased.[68]

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[61]Thiele, loc. cit. [62]Davis, loc. cit.

[63]Clarke, loc. cit. [64]Clarke, loc. cit.

[65]Clarke, Shay, and Mathews, loc. cit.

[66]Thiele, loc. cit. [67]Davis, loc. cit.

[68]Winslow, Herrington, and Gagge, loc. cit.

Two studies suggested that under static room temperature, the skin temperature is determined by the heat flow to the skin and the heat losses from the body surface.[69] One study revealed that deep body cavities have surface temperatures close to the internal body temperature. The same study also concluded that the equilibrium temperature of skin usually falls somewhere between 29 degrees and 35 degrees Centigrade within a static room temperature 23 degrees Centigrade and free from air currents.[70] One research study indicated that induced emotional stress created a significant increase in skin temperature. Thermography was used to measure skin temperature in five research studies that were reviewed.[71] Thermocouples were implemented in the measurement of body surface temperature in three studies.[72] A thermistor thermometer was used to measure skin temperature in one study.[73] An infrared radiometer was the principal instrument used for skin temperature measurement in one study.[74] Some other studies utilized the radiometer in conjunction with thermography research. Thermography was used in one study in the diagnosis of rheumatoid arthritis.[75] One study illustrated the use of thermography in the field of obstetrics.[76] One study was conducted using thermography in the detection of breast

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[69] Barnes ; van der Staak; loc. cit.

[70] Barnes , loc. cit.

[71] Boas; Gershon-Cohen, Haberman-Brueschke, and Brueschke; Gershon-Cohen and others; Albert, Glickman, and Kallish; Barnes; loc. cit.

[72] van der Staak; Loiselle; Eckerson; loc. cit.

[73] O'Connell, loc. cit. [74] Barnes , loc. cit. [75] Boas, loc. cit.

[76] Gershon-Cohen, Haberman-Brueschke, and Brueschke, loc. cit.

cancer.[77] Another study instituted thermography to study orthopedic problems.[78] There was one reference to the use of thermography in the study of vascular disease.[79]

One study was surveyed concerning the effects of isometric exercise on skin temperature. A significant temperature increase was revealed.[80] Another study found that skin temperature increased with humidity and showed an even greater increase under high temperature and humidity.[81] One study indicated that the skin temperature during exercise declines in direct relation to a decrease in ambient temperature.[82] Two studies revealed an existence of symmetry in the skin temperature of foot surface stress areas after exercise.[83]

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[77]Gershon-Cohen and others, loc. cit.

[78]Albert, Glickman, and Kallish, loc. cit.

[79]Gershon-Cohen, Haberman-Brueschke, and Brueschke, loc. cit.

[80]O'Connell, loc. cit.

[81]Loiselle, loc. cit.

[82]Eckerson, loc. cit.

[83]Apple; Collins; loc. cit.

CHAPTER III

PROCEDURE OF THE STUDY

OVERVIEW

Sixty high school and college males served as subjects. Each subject was introduced to the procedures of the study by means of an orientation period. This allowed the subject to gain familiarity with the test instruments and protocol of the study.

When the subject reported for testing, the investigator marked the five anatomical locations of the thigh and knee joint which were to be checked for skin surface temperature. The subject then sat for fifteen minutes with the knees flexed at 110 degrees to allow the skin temperature to stabilize with the room temperature.

Pre-exercise skin temperature recordings of the five selected anatomical locations of the thigh and knee joint were acquired. After a brief standardized warmup period, the subjects were tested for pre-exercise isometric strength of the knee extensors and flexors with the knee joint at 125 and 160 degrees, respectively. The same procedures were employed in the strength measurement of the extensors as the flexors except that the right and left extensor strength was tested separately.

Following a treadmill run for each of two experimental conditions, strength decrement measures were taken in the same manner as the pre-exercise measures, except that only one maximum pull was required. The order of strength testing for the two muscle groups was rotated systematically throughout the study. The post-exercise skin temperature measurements were repeated every two minutes until a peak temperature was observed in each body surface location of the thigh and knee joint.

The subjects followed a counterbalanced testing schedule in completing the ten-minute treadmill run under each of two conditions: (1) ankles taped, and (2) ankles untaped. The two testing sessions for each subject were spaced about one week apart. Each testing session required an indefinite period of time because of the individual differences in reaching peak skin temperatures. The entire study encompassed a time period of six weeks.

SELECTION OF SUBJECTS

The subjects that volunteered for this study included high school and college males from Louisiana State University and University Laboratory School, Baton Rouge, Louisiana. The majority of the students from Louisiana State University were enrolled in the basic instruction classes in the Health, Physical and Recreation Education Department. Each high school student that participated was a senior. The investigator met all potential subjects to discuss their possible participation and to familiarize them with the procedures of the study. Pertinent details of the study, such as the importance of the study, the time required, the location, and the necessary dress were discussed.

TESTING APPARATUS AND EQUIPMENT

Torque Table - The Drury-Broussard Torque Table,[1] an instrument designed to measure the amount of force exerted by the muscles of the legs and arms, was used in this study to measure the isometric strength of the knee flexors and extensors. (Figure 1). The strength measurement device was equipped with a torqueometer* which contained a foot-pound gauge to indicate the numerical value of strength. The torque table was also provided with arm and leg levers which were adjustable in length and angle of pull. Prior to the strength test in the pilot study, the torqueometer was calibrated by hanging weights from the adjustable leg lever.

Stop Watch - A stop watch was used to time the treadmill run and the necessary time intervals in the measurement of skin temperature and static strength.

Nylon Webbing Belt - An adjustable belt, made of nylon webbing, was utilized to firmly secure the subject to the table during the strength measurement of the knee flexors and extensors. The belt was securely placed over the pelvis for the knee extension strength testing and applied over the buttocks for the strength assessment of the knee flexors.

Goniometer - A goniometer was constructed to measure the knee joint angle for the skin temperature measurements in this study. Two plastic

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[1]Francis A. Drury, "The Torque Table" (Louisiana State University, 1960), (Mimeographed.)

*Manufactured by the Snap-On Tool Corporation, Kenosha, Wisconsin.

arms were affixed to a 180 degree plastic protractor. One arm was made stationary along the zero degree line. The other arm was movable and could be rotated to acquire a desired joint angle.

Treadmill - The treadmill run required in the study was performed on a Quinton Treadmill, Model 18-49-C.** The treadmill was designed for speeds from one to ten miles per hour and a range in grade from 0 to 40 per cent.

Infrared Thermometer (Radiometer) - A Barnes Medical Thermometer, Model MT-3,*** was employed in this study to obtain the skin temperature measurements. The heat detection device measured instantly in either Centigrade or Fahrenheit degrees on a meter to accuracies of less than one-tenth degree Centigrade. The sensing head of the portable instrument could be mounted on a tripod built into a fixture or held by hand. The hand-held radiometer was used in this study.

The Barnes Reference Standard**** was used to calibrate the hand-held radiometer. The reference standard consisted of a 76 MM IMM Fisher mercury thermometer and a water container covered with a plastic lid that contained a cylindrical-shaped plastic cavity to allow for the insertion of the hand-held radiometer cone. By placing water in the container and adding ice to gradually cool the water, a comparison of the temperatures registered by the mercury thermometer and the hand-held radiometer was made at twenty-minute intervals.

**Manufactured by the Quinton Instruments Co., Seattle, Washington.

***Manufactured by Barnes Engineering Co., Stamford, Connecticut.

****Manufactured by Barnes Engineering Co., Stamford, Connecticut.

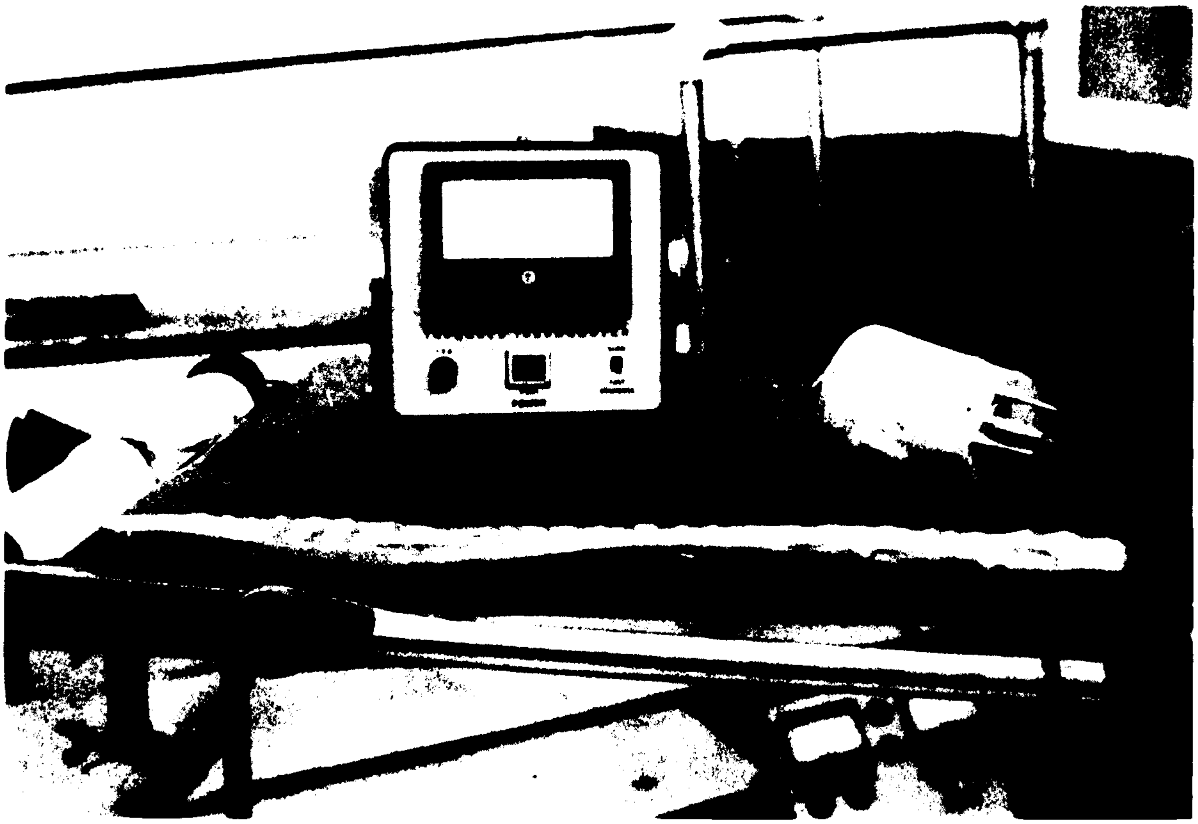

Figure 1

Strength-Testing and Skin Temperature Measurement Apparatus, Including the Barnes MT-3 Infrared Thermometer, Drury-Broussard Torque Table With Torqueometer, Leg Lever, and Padded Cross Bar

Table - A wooden table, approximately three feet in height, served as a training table for the ankle taping in this study.

Stool - A metal stool with a cushioned seat was utilized to insure standardization of body position for the body surface temperature measurements. Each subject assumed a natural sitting position with the knees flexed at 110 degrees. This position was maintained throughout the time of the pre and post-exercise skin temperature measurements.

Thermometer - A mercury thermometer was used to maintain an ambient room temperature of 68 to 78 degrees Fahrenheit during the complete administration of the study.

ANKLE TAPING PROCEDURE

The type of ankle taping employed in this study was a modified Gibney (basket weave) technique with heel lock. Morehouse and Rasch[2] cited two studies by former students which indicated this taping procedure to give the greatest support of a number of strappings tested. Dr. Martin J. Broussard, Supervisor of Athletic Training at Louisiana State University and former United States Olympics trainer, recommended this preventive ankle strapping for use in the study.

A student trainer from the Louisiana State University Athletic Department applied the ankle strappings to each of the subjects involved in the study. The student trainer was urged to tape the ankles the same as he would for athletes prior to competition, and he was also asked to tape the ankles as consistently as possible from subject to subject.

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[2]Laurence E. Morehouse and Philip J. Rasch, Sports Medicine for Trainers (Philadelphia: W. B. Saunders Company, 1963), p. 169.

During the application of the modified Gibney with heel lock technique, the subject sat in an upright position with the arms parallel to the side of the body and the hands grasping the edges of the table just lateral to the hips. Prior to taping the ankle, extreme caution was taken in positioning the subject's leg to prevent possible discomfort or injury. The hip was flexed approximately 90 degrees, the leg fully extended, and the ankle positioned in normal dorsiflexion with slight eversion.

A liquid adherent (Cramer's Q.D.A.*****) was applied directly to the skin surface area which was to be taped. A small four-by-four inch pad, cut from Johnson & Johnson's Sofrol wrappings,****** was positioned approximately two inches above the malleoli and extended down toward the calcaneus, covering the attachment of the Achilles tendon to this bone. Another pad was then placed across the anterior surface of the ankle joint mortice area.

A base strip was applied approximately four inches above the malleoli. The longitudinal strips were then applied. Beginning on the posterior medial surface of the ankle, the first longitudinal strip was affixed under the calcaneus and extended along the posterior lateral aspect of the ankle and then attached to the base strip at the lower part of the leg. The second longitudinal strip was split anteriorly from the first strip approximately one-half inch in length. In applying the third longitudinal strip, caution was taken to locate the strip

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*****Manufactured by Cramer Products, Inc., Gardner, Kansas.

******Manufactured by Johnson & Johnson, New Brunswick, New Jersey.

behind the base of the fifth metatarsal. After the third longitudinal strip was applied, the three strips were securely affixed to the leg at their point of initiation by two to three circular strips. Three longitudinal strips were used for all normal sized ankles with the third strip overlapping the second as the tape was moved anteriorly.

In applying each of the longitudinal strips, caution was taken to maintain an application of steady, consistent pressure pulling down from the medial side of the ankle underneath the heel and on to the end of the strip. The application of the ankle strapping tape was closely observed throughout the taping procedure to insure an absence of wrinkles.

The transverse strips were applied immediately after the application of the longitudinal strips. Beginning on the medial side at about the center of the longitudinal arch, a steady and consistent amount of pressure was exerted as the first transverse strip was brought behind the heel and continued along the lower lateral aspect of the ankle with the strip ending parallel to the medial edge of the strip. The second transverse strip was split approximately one-half inch above the first strip and assumed the same angle of support with steady, consistent pressure being applied from the medial to the lateral side. The third transverse strip overlapped the second strip by one-half inch as the tape was moved up the ankle.

The next step in the ankle taping procedure was the application of the heel lock taping technique. The first strip began at an oblique angle that was posterior and inferior to the medial malleolus. The strip was applied underneath the heel toward the outside while remaining behind the base of the fifth metatarsal and extending across the anterior aspect of the ankle joint mortice. The strip was continued across the medial malleolus and then moved behind the posterior aspect of the calcaneus. The application of the first strip in the heel lock taping method was consummated by continuing the tape laterally and inferior to the lateral malleolus, moving the strip underneath the foot, and ending the strip at the apex of the ankle.

The application of the next strip in the heel lock technique began from an oblique angle posterior and inferior to the lateral malleolus. The strip was then affixed underneath the foot and extended upward medially across the apex of the foot. The strip was continued across the lateral malleolus by moving behind the lateral aspect of the calcaneus and behind the heel underneath the foot medially. It was then brought across the bottom of the heel while remaining behind the base of the fifth metatarsal. The application of the strip was terminated at a lateral angle on top of the ankle joint.

Transverse strips were continually applied up the ankle and lower leg until the whole area was closed and firmly supported. Another base strip was then applied at the top of the strapping.

The "closing off" of the strapping was performed with the pressure being exerted from the lateral side of the foot underneath, pulling up on the longitudinal arch. This usually required the application of three strips. The first strip began near the ankle joint with the second and third strips being initiated in a like manner and continued down toward the toes.

After the ankles were taped, the subject removed his shirt, then put on shoes and socks and proceeded to wait fifteen minutes to allow the tape to "set" and also to permit the skin to stabilize with the ambient room temperature.

PROCEDURES FOR THE MEASUREMENT OF SKIN TEMPERATURE

Skin temperature recordings were obtained with the Barnes Infrared Thermometer. The subject was clad in gym shorts, socks, and tennis shoes.

1. The radiometer was turned on at least twenty minutes before the pre-exercise skin temperature recordings were taken to allow for its stabilization. The investigator located the five body surface areas of both legs and marked them with a small application of gentian violet. The gentian violet was used to insure consistency in locating the skin temperature areas the following week under the second experimental condition. The five body locations that were measured included: (1) the belly of the rectus femoris, (2) the belly of the biceps femoris, (3) the medial collateral ligament, (4) the lateral collateral ligament, and (5) the quadriceps tendon. (Figure 2).
2. During the sessions when the ankles were both untaped and taped, the subject sat quietly on a stool for a fifteen-minute period prior to testing to permit the skin to come into equilibrium with the environment. At the session when the ankles were taped, this fifteen-minute period was used

for skin temperature adjustment and as a tape "setting" period. The ambient room temperature was held between 68 and 78 degrees Fahrenheit.

3. The investigator acquired the skin temperature readings of the selected body surface locations within a two-minute period prior to the one-minute treadmill warmup and the strength measurement procedure. The investigator used the hand-held radiometer while an assistant read and recorded the skin temperature of the selected areas. To assure the distance from the cone of the radiometer to the skin to be consistent at one-fourth inch, three wooden golf tees, two inches in length, were glued securely to the head of the radiometer to which the one and three-fourths inch cone was attached. (Figure 2).

During the skin temperature measurement at each body surface area, care was taken to barely touch the skin with the golf tees. This removed the possibility of causing any discomfort to the subject and helped to insure consistency in maintaining the proper distance from the skin surface to the end of the radiometer cone.

Immediately after the two-minute time period for pre-exercise skin temperature measurement expired, the subject began the one-minute warmup run on the treadmill. Post-exercise temperature recordings were taken immediately after the strength decrement measurements. The anatomical areas designated for skin temperature assessment were measured at two-minute intervals for at least fifteen minutes after the treadmill run and thereafter until all ten areas had peaked in temperature increment.

Figure 2

Skin Temperature Measurement of the Quadriceps Tendon and the Belly of the Rectus Femoris, Utilizing the Barnes MT-3 Infrared Thermometer

ISOMETRIC STRENGTH TESTING PROCEDURES

Knee extension and flexion strength was measured through the use of the Drury-Broussard Torque Table. Correct body position had to be considered along with the choice of knee joint angles for both flexion and extension. Studies by Berger,[3] Clarke,[4] Campney and Wehr[5] indicated that knee extension strength is greater in joint angles between 105 degrees and 140 degrees. As previously mentioned, the torque table contains leg levers which are adjustable in the angle of pull. A leg lever angle of 125 degrees was used in this study. In studying knee flexion strength by use of cable-tension strength testing, Clarke[6] found the mean of peak strength to be near 160 degrees. A leg lever angle of 160 degrees was utilized in this study to measure knee flexion strength. The positioning of the subject for the pre and post-exercise strength measurements was uniform.

The following procedures, as described by Sterling,[7] were implemented in the pre-exercise strength testing procedure:

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[3]Richard A. Berger, "Leg Extension Force at Three Different Angles," The Research Quarterly, XXXVII (December, 1966), 560-562.

[4]H. Harrison Clarke, Muscular Strength and Endurance in Man (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1966), pp. 49-50.

[5]Harry K. Campney and Richard W. Wehr, "An Interpretation of the Strength Differences Associated with Varying Angles of Pull," The Research Quarterly, XXXVI (December, 1965), 403.

[6]Clarke, op. cit., pp. 40-41.

[7]Duane Ray Sterling, "A Comparative Study of the Position Selectivity of Isometric Strength Changes Resulting from Isometric Exercise" (unpublished Master's thesis, Louisiana State University, Baton Rouge, 1964), p. 75.

<u>Knee Flexion Strength Testing</u>

1. The subject assumed a prone position with the patella located at the edge of the table. The subject grasped the sides of the front legs of the table with the hands to give a firm support. (Figure 3).
2. A nylon webbing belt was secured firmly around the buttocks of the subject to prevent movement in the lower trunk. (Figure 3).
3. The leg lever of the torque table was then adjusted to a 160 degree angle of pull. (Figure 3).
4. The padded cross bar which was attached to the leg lever was adjusted to make contact on the posterior aspect of the distal end of the tibia of each leg, about two inches above the ankle joint mortice. (Figure 3).
5. At the investigator's command, the subject exerted maximum effort by pulling steadily on the cross bar for five seconds. The investigator watched the dial of the torqueometer during the exertion while his assistant timed the strength measurement. (Figure 4). The command used by the investigator to initiate the subject's maximum exertion was the term, "pull," while the assistant used the expression, "stop," to terminate the exertion. Two pulls within thirty seconds were required. Following each measurement, the investigator informed the assistant of the strength score. The assistant recorded the strength value of each pull, but in the statistical analysis of the data, only the best strength value was

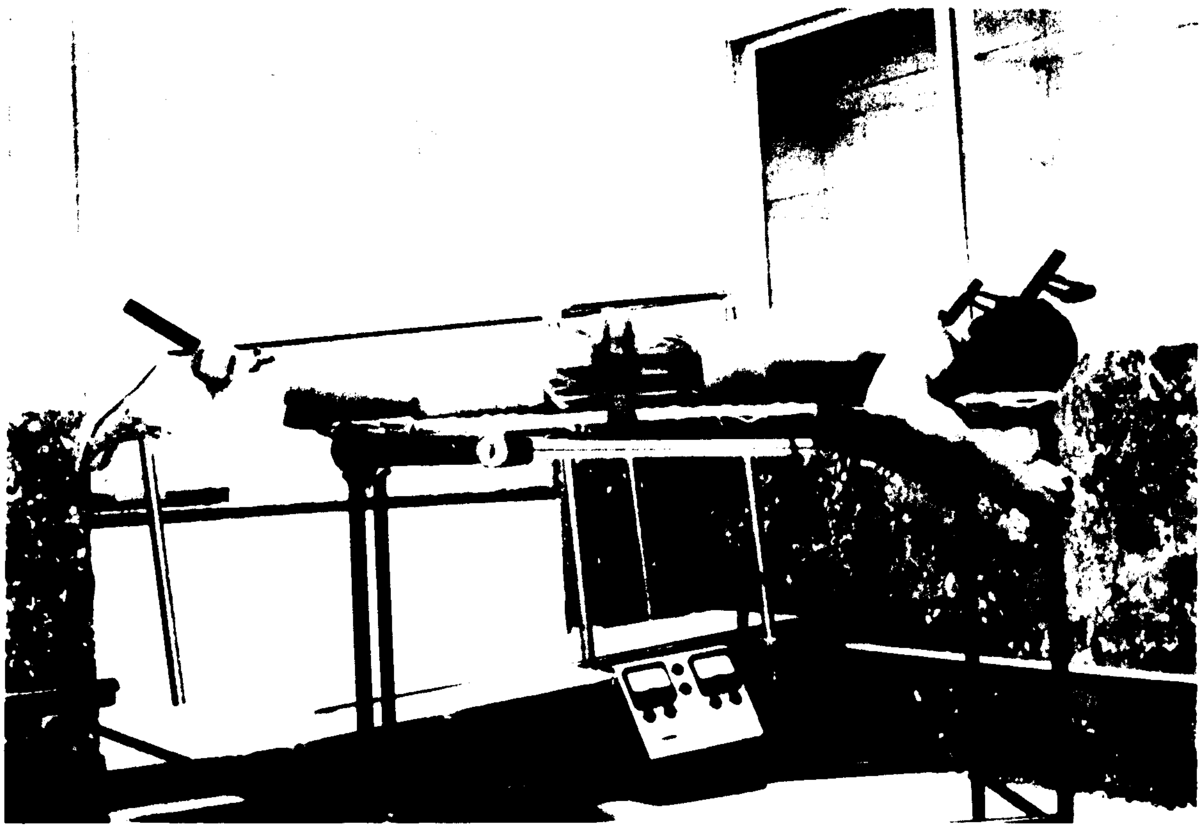

Figure 3

Position of Subject During the Static
Strength Measurement of the
Knee Flexors

considered. The best score was recorded to insure greater probability in obtaining the maximum knee flexor strength of the individual.

Knee Extension Strength Testing

1. The subject assumed a supine position with the head resting on the table and the hands grasping the back of the table. (Figure 4).
2. The nylon webbing belt was placed securely around the pelvis of the subject to insure isolation of the knee extensors. (Figure 4).
3. The leg lever of the torque table was adjusted to an angle of 125 degrees. (Figure 4).
4. The padded cross bar was adjusted to make contact at the anterior aspect of the distal end of the tibia of the right leg, about four inches above the ankle joint mortice. (Figure 4).
5. Following the same testing procedure that was used in measuring the knee flexor strength, two five-second maximum pulls on the leg lever were completed within thirty seconds with the highest strength value of the two pulls being recorded.
6. Although the cross bar was padded with foam rubber, a towel was placed between the bar and subject's shin to remove the possibility of pain or discomfort when the subject exerted force against the bar.
7. The isometric strength of the left extensor was then tested using the same standardized procedure.

Figure 4

Position of Subject, Investigator, and
Assistant During the Static Strength
Measurement of the Left Knee
Extensor Muscles

The strength measurements for knee flexion and extension were rotated systematically throughout the study. As suggested by Clarke[8] and Start,[9] a one-minute warmup period of treadmill running was completed immediately prior to the pre-exercise strength measurements and immediately after the pre-exercise skin temperature measurements. A one-minute preparation period for pre-exercise strength measurements was required between the one-minute treadmill warmup and those measurements.

STRENGTH DECREMENT PROCEDURES

One minute after the ten-minute treadmill run, the strength testing procedures were employed in the same manner as the pre-exercise measurements except that only one maximum pull for both knee flexion and extension was required. If more than one pull had been required, the strength decrement could have been partially due to the repeated contractions instead of the treadmill running conditions.

ORIENTATION PROCEDURE

To exhibit complete understanding of a task to be performed unquestionably contributes to the successful execution of that task. The investigator conducted a familiarization session with the subjects who participated in the study. Since it was not feasible to allow each

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[8] H. Harrison Clarke, "Strength Decrement of Muscles of Trunk and Lower Extremities from Sub-Maximal Treadmill Running," The Research Quarterly, XXVIII (May, 1957), 96.

[9] K. B. Start, "Incidence of Injury to Muscles Undergoing Maximum Isometric Contraction Without Warm-up," Archives of Physical Medicine and Rehabilitation, XLIII (June, 1963), 28-36.

subject a "dry run" of his assigned task, the investigator urged the subject to strictly adhere to every instruction given during the orientation session.

The investigator demonstrated the treadmill run technique to the group. Each subject was given an opportunity to familiarize himself with the treadmill exercise by completing a practice run of one minute.

Certain restrictions and conditions concerning the skin temperature phase of the study were explained to the subjects. The subject was urged to refrain from smoking and eating for at least three hours prior to testing. At this time, he was also informed of the dress required for skin temperature measurements and also the absolute necessity of minimum body movement during the skin temperature stabilization period and the pre and post-exercise skin temperature measurement periods.

The subjects were also introduced to items pertinent to the strength measurement phase of the study. The subjects were given an opportunity to learn the required strength testing procedures to be implemented on the Drury-Broussard Torque Table. Each subject was asked to exert three maximum pulls for both knee flexion and extension. The correct body position was established just as performed in the actual study. The group was further reminded that the attire for all testing would consist of tennis shoes, gym shorts, and socks.

An orientation session was also conducted for the student trainer who read and recorded the skin temperature measurements in the study. The purposes of the study were explained to the assistant, and he was introduced to the research equipment. Practice in reading the skin temperature values which were recorded on the infrared thermometer dial was continued until the assistant demonstrated proficiency in this assignment.

PILOT STUDY

A pilot study was conducted during the fall semester of 1971 at Louisiana State University, Baton Rouge, Louisiana. Ten college male subjects were tested for isometric strength and strength decrement by the use of the Drury-Broussard Torque Table. Skin temperature measurements of selected body surface locations were also obtained from these subjects by the use of a Barnes Infrared Thermometer. The purposes of the pilot study were threefold: (1) to aid in refining the techniques and scope of the study, (2) to determine if significant skin temperature increases in selected knee joint areas were evident after a ten-minute treadmill run at six miles per hour and on a 10 per cent incline, and (3) to determine if significant strength decrement was evidenced in the knee flexors and extensors following the same treadmill run.

Twenty additional subjects were tested and retested on the torque table for knee flexion and extension strength to obtain reliability estimates for strength testing at selected joint angles. Each subject exerted maximum effort in completing three five-second pulls at each strength testing position (leg lever angle of 160 degrees for knee flexor strength testing and leg lever angle of 125 degrees for testing the strength of the knee extensors). Ten minutes later the procedure was repeated. Each individual strength score was derived by adding the foot-pound total of the three pulls.

A reliability coefficient of .89 was found when testing the twenty subjects for knee flexor strength at the above mentioned angle of pull. A reliability coefficient of .97 was obtained when testing knee extensor strength.

The t-test for significance of the difference between correlated means was utilized to analyze the mean gains of the ten subjects from initial to final test concerning skin temperature increases in the five selected anatomical areas of the thigh and knee joint. The investigator assumed the difference in skin temperature increases of the right and left legs to be symmetrical; therefore, only the right leg was considered in computing the differences in pre and post-exercise skin temperature. The temperature increase for each selected body surface area of the right leg was significant at the .01 level of probability. Thus, each of the five anatomical areas were included in the study as body sites to be measured for increment in skin temperatures.

The t-test for correlated means was also used in the analysis of mean negative gains from pre-exercise to post-exercise test regarding strength decrement of the knee flexors and extensors. The strength loss for the flexors, the right extensors, and the left extensors was significant at the .01 level of probability. Therefore, the investigator retained the strength measurement of these muscle groups in the study as originally planned.

In the consideration of a standardized procedure to measure skin temperature, the investigator experimented with several approaches before choosing the method that was implemented (p. 59). Intervals of two minutes were selected because practice in measuring the skin temperature of five anatomical areas in each leg revealed an average measurement time of approximately two minutes. The investigator felt that at least fifteen minutes were necessary for skin temperature measurement in the post-exercise period in order to alleviate the influence of heat loss by evaporation. Fifteen minutes proved to be ample time to allow the skin to dry, thereby insuring heat loss after that time to be chiefly due to radiation.

The pilot study also disclosed an unforeseen problem regarding the use of the Drury-Broussard Torque Table as the instrument to measure static strength of the knee extensors. As previously discussed, the torque table contained leg levers which were attached to a cross bar padded with foam rubber. A few subjects complained of pain and discomfort when exerting a maximum pull against the bar. The investigator rectified the problem by placing a towel between the bar and the subject's shin during the strength testing of the knee extensors (p. 64). A query of the subjects tested thereafter revealed that the use of the towel eliminated the problem.

STATISTICAL PROCEDURES

The data that were statistically analyzed in this study included static strength scores, strength decrement values, pre-exercise skin temperature values, and values representing change in skin temperature as a result of physical exercise.

A randomized block analysis of covariance procedure was utilized to determine whether or not a significant difference existed between two experimental conditions concerning the amount of strength decrement in the knee flexors. The two conditions for comparison were: performing a treadmill run with the ankles taped; and completing an identical run with untaped ankles. The comparison of the strength decrements was conducted by using the pre-exercise static strength values as a covariate. Analysis of covariance was used because a significant relationship was found between initial and strength decrement scores. The relationship was significant at the .01 level of probability.

A randomized block two-by-two factorial analysis of covariance procedure was used to determine whether or not a significant difference existed between the two experimental conditions regarding the strength decrement in the right and left knee extensors. A strength decrement comparison was made by utilizing the pre-exercise isometric strength values as a covariate. A significant relationship was found between the initial and negative gain scores; therefore, the use of analysis of covariance was justified. This relationship was significant at the .01 level of probability.

The randomized block two-by-two factorial analysis of covariance procedure was also used in determining significant differences between the two experimental conditions with regard to skin temperature increase in five selected anatomical areas of both legs. The comparison of skin temperature increases was conducted by using the pre-exercise skin temperature measurement in each selected area as a covariate. In reference to each anatomical area, a significant relationship was determined between the initial and gain scores. The relationships were all significant at the .01 level of probability.

The Pearson product moment coefficient of correlation was used to determine the relationship of skin temperature change in five anatomical areas and strength decrement of the knee flexors and extensors as a result of treadmill running under the two experimental conditions. Coefficients of correlation were computed for the relationship between right and left extensor loss and the increase of skin temperature in each of the five body surface locations.

CHAPTER IV

ANALYSIS AND PRESENTATION OF DATA

INTRODUCTION

The initial analysis of data in this study was concerned with the mean strength decrement values of the knee flexors and extensors of sixty subjects following a treadmill run under each of two conditions: ankles taped and ankles untaped. Mean gains in surface temperature of five selected anatomical areas of the right and left thigh and knee joint resulting from the treadmill running conditions were also analyzed. A t-test for significance of the difference between correlated means was used to compute the significance of these mean gains.

The second analysis of data in this study involved static strength scores and strength decrement values of the knee flexors and extensors of sixty subjects following the above mentioned treadmill runs. A randomized block analysis of covariance procedure was employed to compare the two conditions concerning strength decrement of the knee flexors. Since the right and left extensors were tested separately, a randomized block two-by-two factorial analysis of covariance procedure was implemented to determine the significance of the difference between the two experimental conditions regarding strength decrement of those muscle groups. This procedure allowed for comparison of the strength decrement values of the two experimental conditions, a comparison of strength loss in the right and left legs, and the interaction of these variables.

The third analysis of data consisted of skin temperature increases in five selected thigh and knee joint areas of the sixty subjects as a result of the two treadmill running conditions. Five separate randomized block two-by-two factorial analysis of covariance procedures were used to denote the extent of the differences in the following comparisons: skin temperature increase in the particular anatomical area resulting from a treadmill run with and without the ankles taped, skin temperature increase of each selected area in the right and left leg, and the interaction of these variables.

The Pearson product moment coefficient of correlation procedure was used to determine the relationship between the strength decrement of the knee flexors and extensors and the skin temperature increase in the five body surface areas of the thigh and knee joint. The above mentioned coefficients of correlation were computed for each of the experimental conditions.

ANALYSIS OF MEAN STRENGTH DECREMENT VALUES OF KNEE FLEXORS AND EXTENSORS AND MEAN GAINS OF SURFACE TEMPERATURE IN SELECTED BODY LOCATIONS

Knee Flexor and Extensor Strength Decrement

As shown in Table I, the mean strength decrement of the knee flexors was significant at the .01 level of probability for each experimental condition. The mean strength decrement value resulting from treadmill running with untaped ankles was 11.58 foot-pounds while a value of 20.17 foot-pounds was shown for the taped ankle condition. The t-ratios were 6.00 and 7.03, respectively. Therefore, the knee flexors

TABLE I

SIGNIFICANCE OF THE DIFFERENCES BETWEEN INITIAL AND FINAL MEAN ISOMETRIC STRENGTH VALUES OF SIXTY SUBJECTS RESULTING FROM TREADMILL RUNNING UNDER TWO EXPERIMENTAL CONDITIONS

Running Condition and Muscle Group	N	Initial Score Mean (Foot-pounds)	Final Score Mean (Foot-pounds)	Difference	SE Diff.	t	P
Knee Flexors (Untaped Ankles)	60	161.50	149.92	11.58	1.93	6.00	.01
Knee Flexors (Taped Ankles)	60	168.50	148.33	20.17	2.87	7.03	.01
Right Knee Extensors (Untaped Ankles)	60	199.50	183.83	15.67	2.65	5.91	.01
Right Knee Extensors (Taped Ankles)	60	203.92	187.09	16.83	2.82	5.97	.01
Left Knee Extensors (Untaped Ankles)	60	197.58	189.75	7.83	3.16	2.48	.05
Left Knee Extensors (Taped Ankles)	60	206.58	196.41	10.17	3.69	2.76	.01

t needed for significance at .01 level of probability = 2.66

t needed for significance at .05 level of probability = 2.00

revealed a significant strength decrement for each of the two treadmill running conditions.

The mean strength decrement value of the right knee extensors was significant for each of the experimental conditions. Treadmill running with untaped ankles produced a mean strength decrement of 15.67 foot-pounds, and a decrement of 16.83 foot-pounds resulted from running with taped ankles. The strength decrement values were significant at the .01 level of probability with t-ratios of 5.91 and 5.97, respectively.

Under each treadmill running condition, the strength decrement value for the left knee extensors was significant. The mean decrement of 7.83 foot-pounds for the untaped ankle condition was significant at the .05 level of probability, as revealed by a 2.48 t-ratio. The mean strength decrement value for running with taped ankles was 10.17 foot-pounds, which was significant at the .01 level of probability. The t-ratio for this comparison was 2.76.

The above analysis of data indicates that significant strength decrement of the right and left knee extensors resulted from both conditions of treadmill running.

Surface Temperature Increases of Five Anatomical Areas

For the purpose of determining the significance of surface temperature mean gains, the area surface gains of each leg were combined. This was due to evidence of bilateral symmetry in skin temperature change as revealed in the literature and also the findings of the pilot and actual study.

As indicated in Table II, the mean temperature gain of each anatomical location under each experimental condition was highly significant at the .01 level of probability. The t-ratios of 28.67 and 24.65 reflect the significance of mean temperature gains of the rectus femoris muscles as a result of treadmill running with untaped and taped ankles. The mean gains were 1.41 degrees Centigrade for the untaped ankle condition and 1.21 degrees Centigrade for the taped ankle condition.

For the untaped ankle running condition, t-ratios of 23.53, 19.17, 22.27, and 27.57 denote the significance of mean surface temperature gains of the quadricep tendons, lateral and medial collateral ligaments, and the biceps femoris muscles. The mean gains were 1.49, 1.00, 1.16, and 1.41 degrees Centigrade, respectively. In reference to the treadmill run with taped ankles, the mean temperature gains for the above mentioned anatomical areas were 1.46, .97, 1.16, and 1.40 degrees Centigrade, with t-ratios of 23.89, 17.14, 22.80, and 25.15.

Thus, treadmill running under both experimental conditions produced significant mean surface temperature gains in all five thigh and knee joint locations.

COMPARISON OF TREADMILL RUNNING UNDER TWO EXPERIMENTAL CONDITIONS REGARDING STRENGTH DECREMENT OF THE KNEE FLEXORS AND EXTENSORS

Knee Flexors

The differences in strength decrement of the knee flexors in sixty males when exposed to two experimental conditions, treadmill running with taped ankles and treadmill running with untaped ankles, were

TABLE II

SIGNIFICANCE OF THE DIFFERENCES BETWEEN INITIAL AND FINAL MEAN SURFACE TEMPERATURE INCREASES OF FIVE ANATOMICAL AREAS IN THE LOWER EXTREMITIES OF SIXTY SUBJECTS RESULTING FROM TREADMILL RUNNING UNDER TWO EXPERIMENTAL CONDITIONS

Belly of Rectus Femoris = BRF
Quadriceps Tendon = QT
Lateral Collateral Ligament = LCL
Medial Collateral Ligament = MCL
Belly of Biceps Femoris = BBF

Untaped Ankles = UA
Taped Ankles = TA

Running Condition and Surface Area	N	Initial Score Mean (Degrees Centigrade)	Final Score Mean (Degrees Centigrade)	Difference	SE Diff.	t	P
BRF-UA	120	31.23	32.64	1.41	.049	28.67	.01
BRF-TA	120	31.49	32.70	1.21	.049	24.65	.01
QT-UA	120	30.86	32.35	1.49	.063	23.53	.01
QT-TA	120	31.07	32.53	1.46	.061	23.89	.01
LCL-UA	120	30.96	31.96	1.00	.052	19.17	.01
LCL-TA	120	31.08	32.05	0.97	.057	17.14	.01
MCL-UA	120	30.75	31.91	1.16	.052	22.27	.01
MCL-TA	120	30.88	32.04	1.16	.051	22.80	.01
BBF-UA	120	30.75	32.16	1.41	.051	27.57	.01
BBF-TA	120	30.77	32.17	1.40	.056	25.15	.01

t needed for significance at .01 level of probability = 2.62

t needed for significance at .05 level of probability = 1.98

compared by covariance. Table III indicates an F-ratio of 2.82 for the comparison between the conditions. In consulting an F table with 1 and 58 degrees of freedom, an F-ratio of 4.01 was found to be necessary for significance at the .05 level of probability. Therefore, the F-ratio of 2.82 did not meet the required test of significance at the .05 confidence level. The adjusted mean negative gain was 13.21 foot-pounds for Condition I (running with untaped ankles) and 18.54 foot-pounds for Condition II (running with taped ankles).

Knee Extensors

Table IV denotes the comparison of the two experimental conditions in producing strength decrement in the right and left knee extensors. A randomized block two-by-two factorial analysis of covariance procedure was used to determine the difference detween the two conditions, the difference of the right and left legs, and the interaction of these variables. Utilizing degrees of freedom of 1 and 176, an F-ratio of .09 was obtained for the two conditions of treadmill running. This F-ratio did not meet the required test of significance at the .05 level of probability. The adjusted means for the two conditions were 13.00 foot-pounds in decrement for the subjects when running with untaped ankles and a 12.25 foot-pound decrement when running with the ankles taped. Therefore, no significant difference was found between treadmill running with the subjects' ankles taped and running without the ankles taped with reference to strength decrement of the knee extensors.

An F-ratio of 9.06 was obtained in the comparison of right and left knee extensor strength. With 1 and 176 degrees of freedom, an F-ratio of 6.78 was necessary to meet the required test of significance

TABLE III

ANALYSIS OF COVARIANCE FOR STRENGTH DECREMENT VALUES OF THE KNEE FLEXORS OF SIXTY SUBJECTS RESULTING FROM TREADMILL RUNNING UNDER TWO EXPERIMENTAL CONDITIONS

Source of Variation	Adjusted Sum of Squares	Degrees of Freedom	Mean Square	F	P
Subject	27,390.13	59			
Treatment	727.74	1	727.75	2.82	NS
Error	14,951.32	58	257.78		
Total	43,069.19	118			

F needed for significance at .01 level of probability = 7.10

F needed for significance at .05 level of probability = 4.01

TABLE IV

ANALYSIS OF COVARIANCE FOR STRENGTH DECREMENT VALUES OF THE KNEE EXTENSORS OF SIXTY SUBJECTS RESULTING FROM TREADMILL RUNNING UNDER TWO EXPERIMENTAL CONDITIONS

Source of Variation	Adjusted Sum of Squares	Degrees of Freedom	Mean Square	F	P
Subject	78,612.26	59			
A (Treatment)	32.41	1	32.41	0.09	NS
B (Leg)	3,276.06	1	3,276.06	9.06	.01
A X B (Treatment X Leg)	4.36	1	4.36	0.01	NS
Error	63,624.24	176	361.50		
Total	145,549.33	238			

F needed for significance at .01 level of probability = 6.78

F needed for significance at .05 level of probability = 3.89

at the .01 level of probability. The adjusted mean negative gains were 16.32 foot-pounds for the right extensors and 8.93 foot-pounds for the left extensors. Thus, there was greater loss of strength in the right extensors.

In testing the interaction of the above variables, an F-ratio of .01 was found, indicating no significant interaction within these variables. This meant that the difference in decrement between the right and left legs was uniform under both experimental conditions. An F-ratio of 3.89 was necessary to meet the required test of significance at the .05 level of probability.

ANALYSIS OF SKIN TEMPERATURE INCREASES AT SELECTED ANATOMICAL AREAS FOLLOWING TREADMILL RUNNING UNDER TWO EXPERIMENTAL CONDITIONS

A randomized block two-by-two factorial analysis of covariance procedure was used to analyze the skin temperature increase at five selected anatomical locations of the thigh and knee joint in sixty subjects resulting from treadmill running under two experimental conditions. The right and left leg were also compared for surface temperature increase, along with the interaction of the variables.

Rectus Femoris

As indicated in Table V, an F-ratio of 10.70 resulted from the comparison of the average skin temperature increase at the belly of the right and the left rectus femoris of sixty subjects. This exceeded the F of 3.89 which was required to meet the test of significance at the .05 level of probability. This indicated that the skin temperature

TABLE V

ANALYSIS OF COVARIANCE FOR SURFACE TEMPERATURE INCREASE OF THE RECTUS FEMORIS MUSCLES OF SIXTY SUBJECTS RESULTING FROM TREADMILL RUNNING UNDER TWO EXPERIMENTAL CONDITIONS

Source of Variation	Adjusted Sum of Squares	Degrees of Freedom	Mean Square	F	P
Subject	50.29	59			
A (Treatment)	1.54	1	1.54	10.70	.01
B (Leg)	0.16	1	0.16	1.14	NS
A X B (Treatment X Leg)	0.10	1	0.10	0.72	NS
Error	25.40	176	0.144		
Total	77.49	238			

F needed for significance at .01 level of probability = 6.78

F needed for significance at .05 level of probability = 3.89

increases of the subjects' rectus femoris muscles were significantly greater during the sessions when the ankles were not taped as opposed to the increases when running with taped ankles. The adjusted mean gains for the experimental conditions were 1.39 degrees Centigrade for the rectus femoris of the subjects during treadmill running with the ankles untaped and 1.22 degrees Centigrade for the same muscle of the subjects when running with the ankles taped.

An F-ratio of 1.14 was obtained when comparing the difference of the right and left leg with respect to surface temperature increase in the belly of the rectus femoris. Therefore, no significant difference in skin temperature increase of the rectus femoris existed between the right and left legs. Adjusted mean gains were 1.33 degrees Centigrade for the rectus femoris of the right leg and 1.28 degrees Centigrade for this muscle in the left leg.

The interaction of the above variables was not significant as reflected by an F-ratio of 0.72. Thus, the differences between the taped and untaped conditions were constant for the right and left legs.

Quadriceps Tendon

An F-ratio of 0.00 is shown in Table VI for the comparisons of treadmill running conditions and the legs regarding surface temperature increase in the quadricep tendons of sixty subjects. This not only indicated a nonsignificant difference between the two conditions and between the quadricep tendons of the right and left legs, but reflected a nonsignificant interaction between the variables. The adjusted mean gain for each condition was 1.47 degrees Centigrade. An adjusted mean gain of 1.47 degrees Centigrade was also revealed in the quadricep tendon of each leg.

TABLE VI

ANALYSIS OF COVARIANCE FOR SURFACE TEMPERATURE INCREASE OF THE QUADRICEP TENDONS OF SIXTY SUBJECTS RESULTING FROM TREADMILL RUNNING UNDER TWO EXPERIMENTAL CONDITIONS

Source of Variation	Adjusted Sum of Squares	Degrees of Freedom	Mean Square	F	P
Subject	63.25	59			
A (Treatment)	0.00	1	0.00	0.00	NS
B (Leg)	0.00	1	0.00	0.00	NS
A X B (Treatment X Leg)	0.003	1	0.003	0.01	NS
Error	36.50	176	0.21		
Total	99.753	238			

F needed for significance at .01 level of probability = 6.78

F needed for significance at .05 level of probability = 3.89

Lateral Collateral Ligament

As shown in Table VII, a nonsignificant difference was found in the comparison of surface temperature increase in the lateral collateral ligaments of sixty subjects after exposure to treadmill running under two experimental conditions. An adjusted mean gain of 0.99 degrees Centigrade was evidenced in the ligaments when the subjects were subjected to treadmill running without taped ankles, while an adjusted mean of 0.98 degrees Centigrade was found in the taped ankle condition. This resulted in an F-ratio of 0.00.

A nonsignificant F-ratio of 2.65 was found for the comparison of the right and left legs of the subjects with respect to skin temperature increase in the lateral collateral ligaments. The adjusted mean temperature gain for the right leg was 1.03 degrees Centigrade, while a gain of .94 degrees Centigrade was found for the left leg. The F-value of 0.25 revealed no significant interaction of these variables.

Medial Collateral Ligament

In the analysis of surface temperature increase of the medial collateral ligaments, Table VIII reveals a nonsignificant F-ratio of 0.33 for the comparison between the two conditions of treadmill running. The subjects showed an adjusted mean gain of 1.14 degrees Centigrade in the medial collateral ligaments following the treadmill sessions that involved non-taped ankles and an adjusted mean gain of 1.18 degrees Centigrade when running with the ankles taped.

An F-value of 1.17 did not meet the required test of significance at the .05 level of probability in the comparison of temperature increase in the subjects' right and left medial collateral ligaments. The

TABLE VII

ANALYSIS OF COVARIANCE FOR SURFACE TEMPERATURE INCREASE OF THE LATERAL COLLATERAL LIGAMENTS OF SIXTY SUBJECTS RESULTING FROM TREADMILL RUNNING UNDER TWO EXPERIMENTAL CONDITIONS

Source of Variation	Adjusted Sum of Squares	Degrees of Freedom	Mean Square	F	P
Subject	48.92	59			
A (Treatment)	0.00	1	0.00	0.00	NS
B (Leg)	0.53	1	0.53	2.65	NS
A X B (Treatment X Leg)	0.05	1	0.05	0.25	NS
Error	35.67	176	0.20		
Total	85.17	238			

F needed for significance at .01 level of probability = 6.78

F needed for significance at .05 level of probability = 3.89

TABLE VIII

ANALYSIS OF COVARIANCE FOR SURFACE TEMPERATURE INCREASE OF THE MEDIAL COLLATERAL LIGAMENTS OF SIXTY SUBJECTS RESULTING FROM TREADMILL RUNNING UNDER TWO EXPERIMENTAL CONDITIONS

Source of Variation	Adjusted Sum of Squares	Degrees of Freedom	Mean Square	F	P
Subject	47.93	59			
A (Treatment)	0.06	1	0.06	0.33	NS
B (Leg)	0.21	1	0.21	1.17	NS
A X B (Treatment X Leg)	0.007	1	0.007	0.04	NS
Error	32.33	176	0.18		
Total	80.537	238			

F needed for significance at .01 level of probability = 6.78

F needed for significance at .05 level of probability = 3.89

left leg increased in temperature 1.19 degrees Centigrade while the right leg gained 1.13 degrees. The interaction of the variables was not significant as revealed by the 0.04 F-ratio.

Belly of Biceps Femoris

As shown in Table IX, the comparison of changes in surface temperature of the biceps femoris muscles resulting from two conditions of treadmill running showed an F-value of 0.00, which was not significant. The adjusted mean gain for each of the two conditions was identical at 1.40 degrees Centigrade. The same adjusted mean gain was found for each leg. Obviously, no significant interaction of the variables was evidenced.

RELATIONSHIP OF SKIN TEMPERATURE INCREASE AND STRENGTH DECREMENT OF THE KNEE FLEXORS AND EXTENSORS AS A RESULT OF TREADMILL RUNNING UNDER TWO EXPERIMENTAL CONDITIONS

The Pearson product moment coefficient of correlation procedure was implemented to procure the relationship of skin temperature increase of five selected anatomical areas of the thigh and knee joint to strength decrement in the knee flexors and extensors following submaximal treadmill running with and without the ankles taped. Assuming the legs to be symmetrical in skin temperature elevation, the temperature increases in paired body parts were combined in the computation of the correlation coefficients.

As indicated in Table X, the coefficients of correlation for knee flexor strength decrement (ankles taped) and skin temperature increase of the rectus femoris, quadriceps tendon, lateral collateral ligament,

TABLE IX

ANALYSIS OF COVARIANCE FOR SURFACE TEMPERATURE INCREASE OF THE BICEPS FEMORIS MUSCLES OF SIXTY SUBJECTS RESULTING FROM TREADMILL RUNNING UNDER TWO EXPERIMENTAL CONDITIONS

Source of Variation	Adjusted Sum of Squares	Degrees of Freedom	Mean Square	F	P
Subject	62.69	59			
A (Treatment)	0.00	1	0.00	0.00	NS
B (Leg)	0.00	1	0.00	0.00	NS
A X B (Treatment X Leg)	0.005	1	0.005	0.03	NS
Error	28.86	176	0.16		
Total	91.555	238			

F needed for significance at .01 level of probability = 6.78

F needed for significance at .05 level of probability = 3.89

TABLE X

RELATIONSHIP BETWEEN STRENGTH DECREMENT OF KNEE FLEXORS AND SKIN TEMPERATURE INCREASE IN SELECTED ANATOMICAL AREAS OF SIXTY SUBJECTS RESULTING FROM TREADMILL RUNNING UNDER TWO EXPERIMENTAL CONDITIONS

	Skin Temperature Increase				
Strength Decrement	Rectus Femoris	Quadriceps Tendon	Lateral Collateral Ligament	Medial Collateral Ligament	Biceps Femoris
Flexor Strength Decrement (ankles untaped) N=60	-.01	.003	.03	.07	-.03
Flexor Strength Decrement (ankles taped) N=60	-.16	-.002	.12	.13	-.25

No relationship was significant at the .05 level of probability medial collateral ligament, and biceps femoris were -.16, -.002, .12, .13, and -.25, respectively. None of these coefficients of correlation reached significance at the .05 level of probability.

In reference to the untaped ankle condition, none of the coefficients of correlation were significant at the .05 level of probability. The relationships between knee flexor strength decrement and the skin temperature increase of the rectus femoris, quadriceps tendon, lateral collateral ligament, medial collateral ligament, and biceps femoris were -.01, .003, .03, .07, and -.03, respectively.

Table XI exhibits the coefficients of correlation for knee extensor strength decrement and skin temperature increase of the aforementioned anatomical areas. The correlation coefficients under the untaped ankle condition revealed two significant relationships. A correlation coefficient of -.25 was noted between the knee extensor strength decrement and temperature increase of the rectus femoris muscles. The relationship was significant at the .01 level of probability. The relationship between the same muscle group and the change of temperature in the medial collateral ligaments showed a correlation coefficient of -.19, meeting significance at the .05 level of probability. The coefficients of correlation for the relationship between knee extensor strength decrement and surface temperature increase in the other three anatomical areas were not significant at the .05 level of probability.

The relationships between the knee extensor decrement and surface temperature increase of the selected anatomical areas (taped ankle condition) were not significant at the .05 level of probability.

TABLE XI

RELATIONSHIP BETWEEN STRENGTH DECREMENT OF KNEE EXTENSORS AND SKIN TEMPERATURE INCREASE IN SELECTED ANATOMICAL AREAS OF SIXTY SUBJECTS RESULTING FROM TREADMILL RUNNING UNDER TWO EXPERIMENTAL CONDITIONS

	Skin Temperature Increase				
Strength Decrement	Rectus Femoris	Quadriceps Tendon	Lateral Collateral Ligament	Medial Collateral Ligament	Biceps Femoris
Extensor Strength Decrement (ankles untaped) N=120	-.25*	-.05	.02	-.19**	-.05
Extensor Strength Decrement (ankles taped) N=120	-.05	.02	.08	.04	-.08

*Significant at .01 level of probability

**Significant at .05 level of probability

Correlation coefficients of -.05, .02, .08, .04, and -.08 were obtained for the rectus femoris, quadriceps tendon, lateral collateral ligament, medial collateral ligament, and biceps femoris.

CHAPTER V

SUMMARY, FINDINGS, DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

SUMMARY

The primary purpose of this study was to investigate the effects of ankle taping upon the strength decrement of the knee flexors and extensors in a submaximal treadmill running performance. A secondary purpose of the study was to determine the effects of ankle taping upon the skin temperature changes of five selected thigh and knee joint locations when subjected to submaximal treadmill running. A sub-purpose of this investigation was to determine the relationship between strength decrement and surface temperature elevation of the knee flexors and extensors. Sixty high school and college males from Louisiana State University and University Laboratory School, Baton Rouge, Louisiana, volunteered as subjects.

The study was conducted in the spring semester of 1972. Each subject completed a ten-minute treadmill run at six miles per hour and at a 10 per cent grade with the ankles taped and without the ankles taped. Static strength tests were administered to the subjects before and after each treadmill run to determine the effects of ankle taping upon static strength decrement of the knee flexors and extensors as a result of exercise by running. The flexors of both legs were tested for strength simultaneously, but the right and left knee extensors were measured for strength separately.

Surface temperature measurements of five thigh and knee joint locations were taken before and after the treadmill runs by the use of a Barnes Infrared Thermometer. The anatomical sites included the belly of the rectus femoris, quadriceps tendon, lateral collateral ligament, medial collateral ligament, and the belly of the biceps femoris. The temperature increases of the five areas were monitored in both legs until each area had peaked in elevation.

Mean scores for pre and post-exercise static strength and skin temperature were obtained for each of the experimental conditions. A t-test for significance of the difference between correlated means was utilized to determine the significance of the strength decrement values and the surface temperature gains. A randomized block analysis of covariance procedure was employed to compare the differences between the two experimental conditions concerning the amount of strength decrement in the knee flexors. A randomized block two-by-two factorial analysis of covariance procedure was utilized to determine whether or not differences existed between the taped and untaped ankle conditions with reference to strength decrement in the knee extensors. The same statistical procedure was used in determining differences between the two conditions regarding skin temperature elevation in five anatomical locations of the thigh and knee joint. Pearson product moment coefficients of correlation were computed to determine the relationship of skin temperature increases in the five body locations and strength loss of the knee flexors and extensors as a result of treadmill running.

FINDINGS

The findings in this study were as follows:

1. There was no significant difference between the effects of treadmill running with the ankles taped and with the ankles untaped regarding the amount of strength decrement in the knee flexors.

2. There was no significant difference between the effects of treadmill running with the ankles taped and with the ankles untaped regarding the amount of strength decrement in the knee extensors.

3. The right extensors exhibited a significantly greater strength loss than the left extensors as a result of treadmill running both with and without the ankles taped.

4. A significantly greater increase in surface temperature of the rectus femoris muscles was found as a result of treadmill running with untaped ankles than following treadmill running with taped ankles. However, there was no difference between the right and left legs.

5. The difference in temperature increases following treadmill running with and without ankle taping was not significant in the quadricep tendons, lateral collateral ligaments, medial collateral ligaments, and biceps femoris muscles. Nor was there a significant difference between the right and left legs for any of the body sites.

6. There were no significant relationships between knee flexor strength decrements and skin temperature increases in either the rectus femoris muscles, quadricep tendons, lateral collateral ligaments, medial collateral ligaments, or the biceps femoris muscles after running with or without taped ankles.

7. A significant relationship between strength decrement of the knee extensors and skin temperature increases in the rectus femoris muscles and the medial collateral ligaments was found for the untaped ankle condition. However, this coefficient was too low for predictive purposes. Under the same treadmill running condition, no significant relationship was found between knee extensor strength decrement and skin temperature increases in the quadricep tendons, lateral collateral ligaments, and biceps femoris muscles.

8. There was no significant relationship between strength decrement of the knee extensors and skin temperature increases in either the rectus femoris muscles, quadricep tendons, lateral collateral ligaments, medial collateral ligaments, or the biceps femoris muscles following treadmill running with taped ankles.

DISCUSSION OF THE FINDINGS

It was believed that the information obtained in this study was too insubstantial to lend any significant credence to the school of thought which charges that preventive ankle taping hastens the onset of fatigue in the knee flexors and extensors and possibly predisposes the knees to injury. However, a finding concerning strength decrement of the knee flexors and an empirical observation by the author during the testing procedure may give some support to the above mentioned thesis.

Although the difference did not quite reach significance at the .05 level of probability, the fact that the subjects displayed an observed mean strength loss of 5.33 foot-pounds greater in the knee flexors when running with their ankles taped than untaped was some indication that preventive ankle taping may contribute to a greater degree of fatigue in the knee flexors.

The finding which revealed a significantly greater surface temperature increase in the rectus femoris muscles when the subjects' ankles were untaped seems somewhat contradictory to the above mentioned finding due to clinical evidence of greater surface temperature elevation in areas of impaired body tissue. However, the assumption that skin temperature elevation represents a stress index for non-injured body parts exposed to stress may be erroneous and as of yet, not confirmed. It was the opinion of the author that skin temperature elevation in non-injured or non-impaired body parts exposed to stress may to some extent, be an indication of the individual's physical condition. In observing the treadmill runs, the author noted that the subjects who had little difficulty in completing the bouts generally displayed a greater surface temperature increase in the selected anatomical areas of the lower extremities than the subjects who experienced some discomfort. The skin surface areas of the better conditioned subjects also tended to peak in elevation sooner than the lesser conditioned individuals. On the basis of this observation, it may be that skin temperature elevation is an index for tissue stress only after injury or impairment occurs. Since convection by means of blood flow is a principal type of body heat emission and a principal function of the arterioles is to distribute the amount of blood flow according to the needs of the tissues, there is a possibility that ankle taping contributed to a greater need for blood in the rectus femoris muscles, thereby reducing the blood supply to the skin and causing the reduction in surface temperature.

If the aforementioned observation is plausible, perhaps it explains the reason for the low relationships between strength decrements and skin temperature increases of the knee flexors and extensors as a result of the treadmill running.

The significant difference found between the right and left knee extensors with regard to strength decrement was expected. The right knee extensors were always assessed for static strength before the left extensors in the pre and post-tests for both experimental conditions; therefore, the significantly greater strength decrement for the right knee extensors was attributed to the greater strength recovery time alloted to the left knee extensors.

The author felt that the ten-minute treadmill run at six miles per hour and a 10 per cent incline was not of sufficient magnitude to adequately compare the difference of the experimental conditions in producing strength decrement of the knee extensors. Several of the subjects made post-test gains on the knee extensor strength measurements. A warmup effect of the muscles could possibly have accounted for the gains. Although a study by Clarke[1] showed a nonsignificant strength decrement of the knee extensors when subjects were exposed to a treadmill run on a horizontal plane at seven miles per hour, the author felt that greater strength decrement would result from running on a 10 per cent grade, especially since the pilot study revealed a significant decrement in the knee extensors of ten subjects upon completion of a

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[1]H. Harrison Clarke, "Strength Decrement of Muscles of Trunk and Lower Extremities from Sub-Maximal Treadmill Running," The Research Quarterly, XXVIII (May, 1957), 95-99.

treadmill run with the same speed and grade as that used in the actual study.

Since the strength testing of the knee flexors and extensors was systematically rotated in the study, the author was interested in the differences of strength decrement in muscle groups when tested one minute after exercise in relation to muscle groups tested three to four minutes following exercise. Three to four minutes after exercise was the approximate time for strength measurement of the second muscle group in the testing order. Of the sixty subjects, thirty were first assessed for strength of the knee flexors and the other thirty tested initially for knee extensor strength. This procedure was followed for both experimental conditions. Utilizing a completely randomized analysis of covariance procedure, the differences in strength loss of the knee flexors for the two time periods were compared for each of the conditions. No significant difference in strength decrement was found for the two time periods under either of the treadmill running conditions. With 1 and 58 degrees of freedom, an F-ratio of 1.17 was computed in the comparison of strength testing times under the untaped ankle condition. The adjusted mean negative gains were 13.74 and 9.43 foot-pounds for the respective time periods of strength testing. An F-ratio of .77 was computed in the comparison of strength testing times for the taped ankle condition. The adjusted mean negative gains were 22.82 foot-pounds for the thirty subjects tested one minute after exercise and 19.38 foot-pounds for the group tested three to four minutes after treadmill running.

The author concluded from these comparisons that submaximal treadmill running either with or without the ankles taped contributed to a significant decrement of knee flexor strength which was still in evidence three to four minutes after exercise.

CONCLUSIONS

Within the limitations of this study, the following conclusions were formed:

1. Ankle taping apparently does not contribute to strength decrement in the knee flexors and extensors during a stressful running performance.

2. There is some evidence that ankle taping retards the normal surface temperature elevation of the knee extensors during strenuous anterior-posterior movement of those muscles.

3. Ankle taping does not appear to affect the normal skin temperature elevation of the quadricep tendons, lateral collateral ligaments, medial collateral ligaments, and biceps femoris muscles during submaximal running.

4. The relationship between skin temperature elevation in the thigh and knee joint and strength decrement of the knee flexors and extensors as a result of a strenuous running performance is negligible.

RECOMMENDATIONS

1. Another study should be conducted to analyze the effects of ankle taping upon strength decrement of the knee extensors, requiring an exercise task considerably more strenuous than the treadmill run used in this study.

2. A study should be conducted to determine the relationship between the cardiovascular condition of individuals performing a

stressful exercise task and the skin temperature change of the involved anatomical areas. The ability to recover from an exhaustive exercise task could also be correlated with the surface temperature change of the involved body parts perhaps by utilizing the time required to reach pre-exercise temperature levels as an indicator of recovery ability.

3. Another study should be conducted to determine the effects of ankle taping upon strength recovery of the knee flexors and extensors following a submaximal running performance.

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APPENDIXES

APPENDIX A

PERSONAL DATA SHEET FOR TESTING SESSIONS

Name__________________________ Date__________ Ambient Room Temperature__________

Height________________________ Weight______________________

Ankles Taped______________________ Ankles Not Taped________________

Testing Order of Muscle Groups______________________________________

Pre-Exercise Skin Temperature

<u>Right Leg</u>

Belly-Rectus Femoris ____________________
Quadriceps Tendon ____________________
Lateral Collateral Ligament ____________________
Medial Collateral Ligament ____________________
Belly-Biceps Femoris ____________________

<u>Left Leg</u>

Belly-Rectus Femoris ____________________
Quadriceps Tendon ____________________
Lateral Collateral Ligament ____________________
Medial Collateral Ligament ____________________
Belly-Biceps Femoris ____________________

Pre-Exercise Strength Measurement

Knee Flexors	Knee Extensors
______________	______________
______________	______________

Post-Exercise Strength Measurement

Knee Flexors	Knee Extensors
______________	______________

APPENDIX A (continued)

Post-Exercise Skin Temperature

0-2 Minutes

	Right Leg	Left Leg
BRF		
QT		
LCL		
MCL		
BBF		

2-4 Minutes

	Right Leg	Left Leg
BRF		
QT		
LCL		
MCL		
BBF		

4-6 Minutes

	Right Leg	Left Leg
BRF		
QT		
LCL		
MCL		
BBF		

6-8 Minutes

	Right Leg	Left Leg
BRF		
QT		
LCL		
MCL		
BBF		

8-10 Minutes

	Right Leg	Left Leg
BRF		
QT		
LCL		
MCL		
BBF		

10-12 Minutes

	Right Leg	Left Leg
BRF		
QT		
LCL		
MCL		
BBF		

12-14 Minutes

	Right Leg	Left Leg
BRF		
QT		
LCL		
MCL		
BBF		

14-16 Minutes

	Right Leg	Left Leg
BRF		
QT		
LCL		
MCL		
BBF		

16-18 Minutes

	Right Leg	Left Leg
BRF		
QT		
LCL		
MCL		
BBF		

18-20 Minutes

	Right Leg	Left Leg
BRF		
QT		
LCL		
MCL		
BBF		

APPENDIX A (continued)

20-22 Minutes

	Right Leg	Left Leg
BRF	______	______
QT	______	______
LCL	______	______
MCL	______	______
BBF	______	______

22-24 Minutes

	Right Leg	Left Leg
BRF	______	______
QT	______	______
LCL	______	______
MCL	______	______
BBF	______	______

24-26 Minutes

	Right Leg	Left Leg
BRF	______	______
QT	______	______
LCL	______	______
MCL	______	______
BBF	______	______

26-28 Minutes

	Right Leg	Left Leg
BRF	______	______
QT	______	______
LCL	______	______
MCL	______	______
BBF	______	______

28-30 Minutes

	Right Leg	Left Leg
BRF	______	______
QT	______	______
LCL	______	______
MCL	______	______
BBF	______	______

30-32 Minutes

	Right Leg	Left Leg
BRF	______	______
QT	______	______
LCL	______	______
MCL	______	______
BBF	______	______

32-34 Minutes

	Right Leg	Left Leg
BRF	______	______
QT	______	______
LCL	______	______
MCL	______	______
BBF	______	______

34-36 Minutes

	Right Leg	Left Leg
BRF	______	______
QT	______	______
LCL	______	______
MCL	______	______
BBF	______	______

36-38 Minutes

	Right Leg	Left Leg
BRF	______	______
QT	______	______
LCL	______	______
MCL	______	______
BBF	______	______

38-40 Minutes

	Right Leg	Left Leg
BRF	______	______
QT	______	______
LCL	______	______
MCL	______	______
BBF	______	______

40-42 Minutes

	Right Leg	Left Leg
BRF	______	______
QT	______	______
LCL	______	______
MCL	______	______
BBF	______	______

42-44 Minutes

	Right Leg	Left Leg
BRF	______	______
QT	______	______
LCL	______	______
MCL	______	______
BBF	______	______

APPENDIX A (continued)

44-46 Minutes

	Right Leg	Left Leg
BRF		
QT		
LCL		
MCL		
BBF		

46-48 Minutes

	Right Leg	Left Leg
BRF		
QT		
LCL		
MCL		
BBF		

48-50 Minutes

	Right Leg	Left Leg
BRF		
QT		
LCL		
MCL		
BBF		

50-52 Minutes

	Right Leg	Left Leg
BRF		
QT		
LCL		
MCL		
BBF		

52-54 Minutes

	Right Leg	Left Leg
BRF		
QT		
LCL		
MCL		
BBF		

54-56 Minutes

	Right Leg	Left Leg
BRF		
QT		
LCL		
MCL		
BBF		

56-58 Minutes

	Right Leg	Left Leg
BRF		
QT		
LCL		
MCL		
BBF		

58-60 Minutes

	Right Leg	Left Leg
BRF		
QT		
LCL		
MCL		
BBF		

APPENDIX B

PRE AND POST-EXERCISE STATIC STRENGTH VALUES*
OF THE KNEE FLEXORS OF SIXTY SUBJECTS
UNDER TWO EXPERIMENTAL CONDITIONS

	Ankles Untaped		Ankles Taped	
Subject	Pre-Exercise Strength	Post-Exercise Strength	Pre-Exercise Strength	Post-Exercise Strength
1	175	155	195	180
2	115	100	145	100
3	170	165	165	135
4	155	105	175	180
5	125	125	145	145
6	175	165	175	155
7	140	135	125	135
8	145	165	170	175
9	195	185	195	180
10	170	125	165	135
11	225	235	245	245
12	220	195	205	145
13	105	85	115	110
14	200	175	185	195
15	175	155	175	140
16	180	185	195	185
17	165	145	175	165
18	140	135	150	150
19	165	145	190	165
20	120	115	175	155
21	155	155	150	120
22	170	175	165	155
23	225	205	215	200
24	175	185	180	170
25	130	130	190	130
26	215	215	215	140
27	200	195	210	205
28	215	225	225	235
29	115	115	135	90
30	195	175	200	175
31	155	135	155	140
32	140	135	145	145
33	115	105	130	115
34	120	85	160	95
35	140	95	145	85
36	215	190	205	195

*Measured in foot-pounds

APPENDIX B (continued)

Subject	Ankles Untaped: Pre-Exercise Strength	Ankles Untaped: Post-Exercise Strength	Ankles Taped: Pre-Exercise Strength	Ankles Taped: Post-Exercise Strength
37	125	120	130	115
38	165	135	160	125
39	135	115	135	145
40	165	135	145	135
41	130	125	165	155
42	105	90	85	85
43	140	140	165	145
44	165	145	175	145
45	165	135	165	160
46	115	110	130	95
47	175	175	175	165
48	115	105	125	75
49	165	190	175	165
50	210	195	235	145
51	190	180	205	195
52	210	205	205	205
53	165	165	165	155
54	155	155	160	145
55	165	155	150	95
56	130	95	130	95
57	110	95	130	105
58	135	135	125	125
59	160	145	155	145
60	255	235	230	210

APPENDIX C

PRE AND POST-EXERCISE STATIC STRENGTH VALUES* OF THE KNEE EXTENSORS OF SIXTY SUBJECTS UNDER TWO EXPERIMENTAL CONDITIONS

R = Right Leg
L = Left Leg

		Ankles Untaped			Ankles Taped	
Subject		Pre-Exercise Strength	Post-Exercise Strength		Pre-Exercise Strength	Post-Exercise Strength
1	R	200	185	R	195	175
	L	205	195	L	205	190
2	R	155	115	R	155	125
	L	215	195	L	205	185
3	R	230	155	R	205	175
	L	240	165	L	205	165
4	R	205	195	R	235	225
	L	200	195	L	215	195
5	R	225	220	R	235	215
	L	235	220	L	225	225
6	R	325	305	R	315	275
	L	325	325	L	305	285
7	R	200	180	R	220	185
	L	200	185	L	215	205
8	R	195	185	R	185	195
	L	175	185	L	195	230
9	R	155	105	R	145	110
	L	150	120	L	155	125
10	R	135	115	R	155	85
	L	115	95	L	105	80
11	R	290	225	R	260	255
	L	250	225	L	240	205
12	R	230	235	R	225	205
	L	230	235	L	225	180
13	R	130	145	R	155	105
	L	115	125	L	155	155
14	R	255	210	R	235	225
	L	215	210	L	195	240
15	R	245	195	R	240	245
	L	235	165	L	235	195
16	R	270	265	R	275	235
	L	255	245	L	275	225

*Measured in foot-pounds

APPENDIX C (continued)

Subject		Ankles Untaped Pre-Exercise Strength	Ankles Untaped Post-Exercise Strength		Ankles Taped Pre-Exercise Strength	Ankles Taped Post-Exercise Strength
17	R	175	155	R	185	180
	L	175	155	L	195	185
18	R	205	195	R	215	210
	L	205	205	L	235	215
19	R	205	165	R	165	135
	L	175	135	L	175	155
20	R	150	115	R	210	155
	L	150	140	L	215	165
21	R	145	125	R	145	85
	L	140	115	L	140	75
22	R	165	140	R	175	140
	L	170	170	L	165	145
23	R	280	295	R	295	275
	L	275	285	L	275	285
24	R	235	240	R	250	245
	L	225	250	L	215	240
25	R	155	120	R	170	125
	L	155	155	L	170	145
26	R	150	170	R	205	155
	L	175	180	L	250	155
27	R	200	200	R	200	190
	L	185	185	L	205	215
28	R	225	210	R	230	235
	L	205	230	L	215	215
29	R	135	105	R	135	95
	L	115	115	L	145	105
30	R	185	125	R	225	195
	L	175	125	L	190	210
31	R	220	215	R	195	190
	L	215	225	L	215	205
32	R	190	200	R	215	225
	L	180	185	L	195	215
33	R	145	105	R	175	175
	L	145	145	L	170	200
34	R	195	135	R	195	145
	L	185	145	L	215	145
35	R	230	195	R	200	225
	L	215	165	L	225	215
36	R	215	180	R	235	240
	L	245	240	L	260	295
37	R	100	95	R	95	130
	L	115	105	L	80	125

APPENDIX C (continued)

Subject		Ankles Untaped Pre-Exercise Strength	Ankles Untaped Post-Exercise Strength		Ankles Taped Pre-Exercise Strength	Ankles Taped Post-Exercise Strength
38	R	155	155	R	190	195
	L	150	115	L	200	195
39	R	180	175	R	180	175
	L	165	165	L	195	180
40	R	245	230	R	215	195
	L	260	245	L	215	215
41	R	215	245	R	245	225
	L	245	255	L	240	255
42	R	170	145	R	155	125
	L	155	145	L	135	140
43	R	185	175	R	205	225
	L	220	215	L	225	245
44	R	210	195	R	225	225
	L	195	175	L	210	215
45	R	220	215	R	245	235
	L	200	185	L	225	205
46	R	255	255	R	235	210
	L	225	245	L	235	185
47	R	215	190	R	195	205
	L	300	285	L	315	290
48	R	175	160	R	145	115
	L	195	165	L	155	140
49	R	215	195	R	175	175
	L	215	175	L	165	185
50	R	270	265	R	260	225
	L	265	255	L	245	195
51	R	180	205	R	175	185
	L	180	195	L	185	185
52	R	295	315	R	315	315
	L	335	325	L	335	335
53	R	300	290	R	280	285
	L	200	240	L	275	265
54	R	130	125	R	95	75
	L	125	90	L	115	115
55	R	125	120	R	175	150
	L	125	130	L	175	190
56	R	180	145	R	170	140
	L	150	155	L	155	155
57	R	175	175	R	225	205
	L	175	195	L	220	200

APPENDIX C (continued)

Subject		Ankles Untaped			Ankles Taped	
		Pre-Exercise Strength	Post-Exercise Strength		Pre-Exercise Strength	Post-Exercise Strength
58	R	155	165	R	165	165
	L	180	195	L	185	180
59	R	185	175	R	185	175
	L	195	210	L	200	215
60	R	185	195	R	230	215
	L	265	285	L	285	305

APPENDIX D

PRE-EXERCISE SKIN TEMPERATURE AND POST-EXERCISE SKIN TEMPERATURE
PEAK OF THREE THIGH AND KNEE JOINT AREAS OF SIXTY
SUBJECTS UNDER TWO EXPERIMENTAL CONDITIONS

Anatomical Areas

BRF = Belly of Rectus Femoris
QT = Quadriceps Tendon
LCL = Lateral Collateral Ligament

Tests

1 = Pre-test Temperature*
2 = Post-test Peak Temperature*

R = Right Leg
L = Left Leg

		Ankles Untaped							Ankles Taped					
		1	2	1	2	1	2		1	2	1	2	1	2
Subject		BRF	BRF	QT	QT	LCL	LCL		BRF	BRF	QT	QT	LCL	LCL
1	R	32.0	33.5	32.2	33.3	31.1	32.4	R	32.9	34.3	33.0	34.2	32.6	33.7
	L	32.3	33.6	32.1	33.4	32.1	32.4	L	33.0	34.1	32.6	34.3	32.5	33.3
2	R	31.3	31.7	31.0	31.5	31.1	31.6	R	32.7	32.6	32.3	32.6	32.5	32.9
	L	31.4	31.9	31.3	31.6	30.9	31.5	L	32.6	32.5	32.3	32.4	32.3	32.1
3	R	33.5	33.7	33.1	33.7	32.7	33.1	R	32.6	32.9	32.1	32.5	31.5	32.1
	L	33.0	33.4	32.4	33.5	32.6	32.7	L	32.1	32.8	31.2	32.3	31.5	32.0
4	R	30.7	33.5	30.4	32.9	30.5	32.6	R	31.0	32.5	30.4	31.5	30.4	31.2
	L	29.9	32.6	30.7	33.6	30.4	32.7	L	30.4	31.9	30.5	32.2	30.4	31.6
5	R	32.9	34.5	32.3	33.5	32.6	33.4	R	30.2	31.8	29.4	31.2	29.8	31.1
	L	32.4	33.4	32.2	34.4	32.1	33.3	L	30.1	31.6	29.7	31.7	30.0	31.1

*Measured in degrees Centigrade

APPENDIX D (continued)

		Ankles Untaped							Ankles Taped					
		1	2	1	2	1	2		1	2	1	2	1	2
Subject		BRF	BRF	QT	QT	LCL	LCL		BRF	BRF	QT	QT	LCL	LCL
6	R	32.5	33.8	32.6	33.7	32.5	33.2	R	32.1	32.9	30.7	31.8	31.2	31.1
	L	32.3	33.3	32.6	32.9	32.4	32.1	L	31.2	32.3	30.5	31.3	30.9	31.1
7	R	31.0	33.2	30.4	32.9	30.2	32.6	R	31.3	33.0	30.2	32.7	30.5	32.6
	L	30.8	32.7	30.2	32.8	30.5	31.4	L	31.4	32.7	30.7	33.0	30.4	32.1
8	R	31.2	31.7	30.5	32.2	30.5	31.0	R	31.8	32.8	31.6	33.0	31.5	32.2
	L	31.6	32.5	30.7	31.6	30.9	31.0	L	32.1	32.3	31.5	32.9	31.4	32.5
9	R	31.3	33.8	30.0	33.2	30.5	32.6	R	31.0	33.0	30.4	32.4	30.6	32.7
	L	31.1	33.2	30.2	32.1	30.1	31.0	L	31.0	32.6	31.0	32.3	30.5	32.0
10	R	30.8	32.2	28.4	32.0	30.3	31.6	R	31.6	32.3	30.6	31.5	31.6	32.3
	L	30.8	32.1	29.1	32.2	30.4	31.9	L	31.4	32.0	30.7	32.6	31.2	32.0
11	R	31.2	32.1	30.7	31.6	29.6	31.4	R	32.4	33.3	31.7	32.9	31.7	31.9
	L	30.7	32.4	30.3	31.7	29.6	30.8	L	32.3	32.9	31.6	32.7	31.2	31.6
12	R	29.7	31.8	29.1	31.9	28.8	31.8	R	31.3	34.4	30.5	34.2	30.1	33.9
	L	29.5	31.4	29.3	32.2	29.3	31.6	L	30.8	34.1	30.1	34.2	30.3	33.2
13	R	31.8	33.3	31.2	32.7	31.6	32.4	R	33.6	34.6	33.2	34.3	33.6	34.0
	L	31.4	32.9	31.2	33.1	31.7	32.7	L	33.3	34.1	33.3	34.6	33.4	33.8
14	R	30.1	31.8	30.3	31.4	30.3	32.0	R	31.2	32.2	31.1	33.0	30.8	32.8
	L	30.2	32.3	30.1	31.8	30.6	31.3	L	31.1	32.8	30.8	32.1	30.8	32.3
15	R	31.2	31.6	30.3	31.3	30.7	31.9	R	31.7	33.0	31.0	33.1	31.0	33.2
	L	31.7	31.9	30.3	32.1	30.6	32.1	L	32.1	33.6	31.4	33.6	31.4	33.4
16	R	30.4	32.8	30.2	32.5	30.7	32.0	R	32.3	34.4	32.0	34.1	32.2	33.4
	L	30.5	33.0	30.3	32.7	30.4	31.8	L	32.4	34.3	32.0	34.3	31.7	33.1
17	R	31.5	32.9	31.4	33.1	31.2	31.9	R	32.9	33.9	32.6	34.1	32.7	33.0
	L	31.3	33.1	30.9	32.8	31.2	31.8	L	32.9	34.0	32.6	33.9	32.7	33.0

APPENDIX D (continued)

Subject		Ankles Untaped 1 BRF	2 BRF	1 QT	2 QT	1 LCL	2 LCL		Ankles Taped 1 BRF	2 BRF	1 QT	2 QT	1 LCL	2 LCL
18	R	32.4	33.5	32.3	33.3	32.6	33.4	R	31.0	32.1	30.5	31.7	31.0	31.6
	L	32.3	33.7	32.0	33.5	32.4	33.1	L	31.0	32.5	30.9	31.9	31.0	31.8
19	R	31.8	32.1	31.9	32.3	32.0	32.7	R	31.2	31.2	31.0	31.1	31.1	31.7
	L	31.8	32.3	31.6	31.7	31.9	32.0	L	31.4	31.4	30.6	30.8	31.1	31.0
20	R	31.8	33.0	31.4	32.9	30.9	32.3	R	31.9	32.9	31.4	32.4	31.0	31.9
	L	31.5	32.6	31.6	32.9	30.9	32.3	L	31.8	32.9	31.3	32.4	31.0	32.2
21	R	30.6	32.4	30.2	32.3	30.2	31.8	R	30.4	32.3	29.8	31.6	29.7	31.2
	L	30.3	32.3	30.4	32.3	30.3	31.7	L	29.7	31.6	29.6	31.6	29.3	31.2
22	R	31.0	31.9	30.5	31.3	30.7	30.8	R	32.6	33.6	32.4	33.4	32.4	33.0
	L	31.1	31.8	30.5	31.8	30.6	30.7	L	32.5	33.7	32.3	33.6	32.0	33.2
23	R	29.4	31.4	29.2	31.2	29.1	30.9	R	31.9	32.8	31.5	32.9	31.5	32.3
	L	29.4	31.6	29.4	31.7	29.4	30.9	L	31.6	33.2	31.3	33.1	31.4	32.1
24	R	30.3	32.3	30.1	32.1	30.5	32.0	R	30.7	31.8	30.7	32.3	30.5	31.5
	L	30.3	32.5	30.0	31.5	30.3	31.8	L	31.2	32.3	30.6	31.9	30.7	31.7
25	R	31.3	32.9	31.2	33.1	31.0	32.4	R	32.0	33.1	31.7	32.6	31.8	32.0
	L	31.3	32.7	30.9	32.4	30.7	31.6	L	31.8	32.5	31.5	32.6	31.4	31.4
26	R	31.5	32.4	31.6	32.5	31.8	32.6	R	31.5	31.8	31.0	32.0	31.1	31.5
	L	31.4	32.4	31.6	32.6	31.8	32.6	L	31.0	32.0	31.0	32.4	30.4	31.7
27	R	30.5	32.8	30.0	32.7	30.3	32.3	R	31.9	34.4	31.0	34.0	31.4	32.7
	L	30.3	32.2	30.1	32.1	30.5	32.6	L	32.0	32.9	31.6	33.6	31.5	33.3
28	R	31.5	32.9	31.0	33.0	31.4	32.6	R	30.2	30.7	29.8	30.7	30.2	29.8
	L	31.5	33.4	31.5	33.1	31.6	31.7	L	30.1	30.8	29.7	30.7	30.0	30.3
29	R	31.4	33.4	30.6	33.4	30.4	32.4	R	31.6	34.2	31.0	34.5	30.2	32.8
	L	31.5	33.1	30.7	33.0	30.7	32.6	L	32.0	34.3	30.7	33.6	30.7	33.0

APPENDIX D (continued)

		Ankles Untaped							Ankles Taped					
		1	2	1	2	1	2		1	2	1	2	1	2
Subject		BRF	BRF	QT	QT	LCL	LCL		BRF	BRF	QT	QT	LCL	LCL
30	R	31.1	32.8	30.7	32.5	30.9	32.4	R	32.2	33.8	31.3	32.7	31.8	32.3
	L	30.9	32.9	30.6	32.6	30.9	32.4	L	32.0	33.6	31.6	32.7	31.5	31.6
31	R	31.9	33.2	31.6	32.0	31.3	31.4	R	31.9	33.8	31.3	32.9	31.4	32.3
	L	31.6	32.6	31.3	31.7	31.4	31.4	L	31.8	33.3	31.4	33.0	31.7	32.3
32	R	30.4	32.1	30.1	31.9	30.9	31.7	R	30.7	32.1	30.6	31.8	30.9	31.5
	L	30.7	31.7	30.6	31.6	30.7	31.1	L	30.4	31.4	30.4	31.3	30.4	30.8
33	R	30.8	32.1	30.7	31.6	30.9	31.2	R	30.7	32.6	30.6	32.2	30.6	31.6
	L	30.7	31.9	30.4	31.2	30.9	31.3	L	30.7	32.5	30.4	31.7	30.7	31.6
34	R	32.1	32.7	31.8	32.6	31.7	32.3	R	32.0	32.4	31.8	32.3	31.6	32.2
	L	32.1	32.7	31.7	32.4	31.6	31.8	L	31.8	32.1	31.8	32.0	31.5	31.3
35	R	32.1	33.1	31.8	33.5	31.4	32.5	R	30.4	31.2	30.2	30.8	30.2	30.8
	L	32.2	33.4	31.7	33.3	31.7	32.5	L	30.5	31.6	30.0	30.7	30.2	30.6
36	R	32.6	33.5	32.1	32.6	32.9	32.2	R	32.5	33.3	32.0	33.2	32.4	32.3
	L	32.6	33.6	32.1	33.0	32.4	32.5	L	32.3	33.2	32.3	32.7	32.3	32.9
37	R	29.6	32.5	28.6	31.9	29.3	31.8	R	30.3	32.2	29.6	31.9	29.8	31.6
	L	29.8	32.0	29.1	31.9	29.1	31.9	L	30.2	31.9	29.8	31.9	30.3	31.7
38	R	32.2	33.7	31.6	32.1	31.9	32.6	R	32.3	32.9	31.9	32.3	31.9	32.6
	L	32.1	33.4	31.3	32.4	31.9	33.1	L	32.3	32.9	31.6	32.3	31.9	33.0
39	R	30.4	32.5	30.1	32.1	30.4	32.2	R	29.7	31.7	29.5	31.7	29.6	31.6
	L	30.4	31.9	30.3	32.1	30.6	32.4	L	29.6	31.3	29.7	31.7	29.7	31.4
40	R	30.8	32.1	30.6	31.7	31.2	31.8	R	32.4	33.8	31.9	33.6	32.5	33.1
	L	30.8	32.2	30.5	32.3	30.7	31.6	L	32.4	33.7	32.2	33.9	31.8	32.3
41	R	30.8	32.1	30.9	32.4	31.2	31.9	R	31.9	33.3	32.2	33.3	32.7	33.1
	L	30.9	32.7	31.1	32.3	31.3	31.8	L	32.3	33.3	32.2	33.0	32.3	32.3

		Ankles Untaped							Ankles Taped					
		1	2	1	2	1	2		1	2	1	2	1	2
Subject		BRF	BRF	QT	QT	LCL	LCL		BRF	BRF	QT	QT	LCL	LCL
42	R	31.4	32.7	30.4	32.7	30.3	31.4	R	32.9	33.5	32.8	33.6	31.9	32.4
	L	31.4	32.6	29.9	32.1	30.7	31.9	L	33.0	33.3	33.4	33.5	32.6	32.9
43	R	31.7	33.0	31.4	32.6	31.5	32.0	R	31.1	32.7	30.6	32.3	31.0	32.3
	L	31.7	32.9	31.3	32.3	31.5	32.4	L	31.2	33.2	30.6	32.6	31.1	32.7
44	R	30.3	31.4	29.8	30.4	29.5	30.4	R	32.2	33.1	31.7	33.5	31.5	32.8
	L	30.0	31.3	29.6	30.7	29.6	30.8	L	32.2	32.9	31.7	33.6	31.5	31.9
45	R	30.5	32.0	30.0	31.8	29.8	31.4	R	30.6	31.7	30.3	31.9	30.4	32.0
	L	30.5	32.0	30.0	31.7	29.8	31.5	L	30.6	32.0	30.1	31.7	30.6	31.9
46	R	29.6	31.6	29.0	31.0	29.4	31.2	R	28.6	30.8	27.7	30.4	28.2	30.1
	L	29.5	31.4	29.0	31.0	29.5	31.1	L	28.8	30.7	28.1	30.6	28.6	30.6
47	R	31.8	33.3	31.5	33.5	31.0	32.3	R	32.8	33.7	32.4	34.0	31.9	32.6
	L	31.5	33.3	31.6	33.5	31.0	32.7	L	32.6	33.6	32.7	33.9	32.2	33.5
48	R	31.7	32.5	31.6	31.8	31.7	31.9	R	30.7	31.1	30.1	30.6	30.6	30.7
	L	31.8	32.2	31.9	32.0	31.6	31.6	L	30.7	30.9	30.3	30.7	30.4	30.7
49	R	31.2	33.2	30.7	32.1	31.1	32.2	R	31.1	32.3	30.6	32.1	30.8	32.0
	L	31.0	32.9	30.6	31.8	30.9	31.8	L	31.0	32.3	30.3	31.9	30.6	31.9
50	R	30.8	32.1	29.5	31.3	30.3	31.1	R	31.6	32.3	31.4	33.6	30.5	31.9
	L	30.8	32.1	30.0	31.4	30.1	31.0	L	31.0	32.3	30.5	32.3	30.4	32.1
51	R	31.9	33.6	31.6	32.9	31.5	32.4	R	29.8	32.3	29.5	31.6	29.5	31.3
	L	31.5	33.3	31.3	32.9	31.5	32.1	L	29.9	31.9	29.3	31.6	29.4	30.9
52	R	30.6	31.6	29.9	30.8	30.2	30.6	R	30.6	32.7	30.6	32.1	30.5	31.9
	L	30.2	31.2	29.7	30.5	30.6	30.6	L	31.1	32.1	30.3	31.8	30.7	31.9
53	R	31.0	33.7	30.2	32.2	30.0	31.6	R	31.3	33.6	30.6	31.8	30.3	31.3
	L	30.8	33.4	30.5	32.8	30.8	31.9	L	31.1	32.4	30.8	32.3	30.8	31.7

APPENDIX D (continued)

		Ankles Untaped							Ankles Taped					
		1	2	1	2	1	2		1	2	1	2	1	2
Subject		BRF	BRF	QT	QT	LCL	LCL		BRF	BRF	QT	QT	LCL	LCL
54	R	31.3	31.5	30.4	31.0	30.7	30.1	R	31.4	32.5	30.8	32.6	30.7	31.7
	L	31.7	32.3	30.6	31.6	31.2	30.7	L	31.6	32.9	31.2	32.4	30.6	31.7
55	R	29.9	31.7	30.1	31.6	30.1	31.3	R	30.6	32.6	29.8	32.3	29.9	32.2
	L	30.3	31.9	30.1	31.6	30.1	31.3	L	30.2	31.8	29.6	32.7	29.7	31.3
56	R	30.6	31.6	31.1	32.1	30.1	31.3	R	31.6	32.5	31.2	32.6	30.9	32.6
	L	30.6	31.6	30.4	31.4	29.9	31.0	L	31.2	31.9	31.2	32.9	30.6	30.5
57	R	32.6	34.3	32.5	33.8	32.4	33.6	R	31.3	32.3	31.3	31.2	31.2	31.0
	L	32.1	34.0	32.2	33.8	32.4	33.9	L	31.2	31.1	31.3	32.0	31.1	31.5
58	R	33.6	33.4	33.2	33.4	33.3	34.0	R	32.2	33.0	31.7	32.4	31.7	32.2
	L	33.2	33.4	33.2	33.3	33.0	33.2	L	31.8	32.4	31.6	32.2	31.7	32.3
59	R	32.4	33.6	32.4	33.2	32.3	32.7	R	32.6	34.0	32.5	33.8	32.0	33.2
	L	32.2	33.7	32.0	33.5	32.0	33.0	L	32.6	33.9	32.3	33.8	32.2	32.6
60	R	32.1	32.6	32.0	32.2	32.0	31.4	R	32.2	32.1	31.6	32.6	31.1	30.9
	L	32.0	32.7	32.0	32.6	32.0	32.3	L	32.3	32.6	31.4	33.0	30.9	32.2

APPENDIX E

PRE-EXERCISE SKIN TEMPERATURE AND POST-EXERCISE SKIN TEMPERATURE PEAK OF TWO THIGH AND KNEE JOINT AREAS OF SIXTY SUBJECTS UNDER TWO EXPERIMENTAL CONDITIONS

<u>Anatomical Areas</u>

MCL = Medial Collateral Ligament
BBF = Belly of Biceps Femoris

R = Right Leg
L = Left Leg

<u>Tests</u>

1 = Pre-test Temperature*
2 = Post-test Peak Temperature*

Subject		Ankles Untaped					Ankles Taped			
		1 MCL	2 MCL	1 BBF	2 BBF		1 MCL	2 MCL	1 BBF	2 BBF
1	R	31.8	32.4	31.9	33.1	R	32.6	33.4	32.9	33.6
	L	31.6	32.8	31.9	33.1	L	32.6	33.7	33.0	34.0
2	R	30.9	31.4	31.0	31.5	R	32.5	32.5	32.6	33.0
	L	31.0	31.1	30.8	31.4	L	32.6	32.5	32.5	32.8
3	R	32.4	33.2	32.6	33.2	R	31.3	31.6	31.5	32.2
	L	32.5	33.5	32.9	33.2	L	31.4	32.1	31.7	32.0
4	R	30.5	32.5	30.6	33.1	R	30.4	31.5	29.7	31.8
	L	30.4	32.2	31.1	33.2	L	29.6	31.3	30.5	32.1
5	R	32.2	33.4	32.1	32.9	R	29.6	31.0	29.3	30.8
	L	32.3	33.4	32.3	33.0	L	29.2	30.9	29.6	31.2

*Measured in degrees Centigrade

APPENDIX E (continued)

		Ankles Untaped					Ankles Taped			
		1	2	1	2		1	2	1	2
Subject		MCL	MCL	BBF	BBF		MCL	MCL	BBF	BBF
6	R	32.8	32.8	32.4	33.1	R	30.9	31.6	30.8	31.3
	L	33.0	33.0	32.6	32.9	L	30.8	31.5	31.0	31.5
7	R	30.0	31.3	30.4	31.4	R	30.0	31.5	29.7	31.7
	L	30.1	32.0	30.0	32.4	L	29.9	32.3	29.7	31.5
8	R	30.8	30.7	29.7	31.2	R	31.9	32.6	31.1	32.6
	L	31.0	31.7	29.5	31.0	L	31.2	32.5	30.7	31.9
9	R	30.0	32.1	30.9	31.8	R	30.3	31.3	30.5	31.6
	L	29.9	31.5	30.8	32.4	L	30.3	31.1	30.0	31.6
10	R	29.9	31.1	29.6	31.6	R	30.6	31.5	30.6	31.9
	L	29.6	31.2	30.1	32.1	L	30.9	31.3	30.7	32.4
11	R	30.0	30.4	29.9	33.4	R	31.4	31.6	30.9	33.4
	L	29.6	31.1	29.4	32.6	L	31.1	32.9	30.6	32.9
12	R	29.0	32.2	29.3	31.1	R	30.3	34.2	30.6	32.3
	L	29.2	31.4	29.8	31.7	L	30.0	33.6	30.7	32.7
13	R	31.3	32.6	31.1	32.3	R	33.6	34.2	32.7	33.9
	L	31.2	32.3	31.3	32.2	L	33.4	33.8	33.1	33.8
14	R	29.8	31.0	29.4	31.5	R	30.8	31.8	30.3	32.3
	L	29.5	31.0	29.4	31.3	L	30.8	31.9	30.6	32.1
15	R	30.2	30.7	30.2	31.2	R	30.8	32.8	31.7	32.4
	L	29.6	30.7	30.1	30.8	L	30.9	32.8	31.4	32.4
16	R	30.8	32.4	29.9	32.0	R	32.6	33.9	31.5	33.7
	L	30.6	32.5	29.9	32.3	L	32.4	34.0	31.8	33.8
17	R	31.2	32.1	31.4	32.3	R	32.6	33.3	32.7	33.5
	L	31.0	32.3	31.8	32.4	L	32.5	33.4	32.7	33.5

		Ankles Untaped					Ankles Taped			
		1	2	1	2		1	2	1	2
Subject		MCL	MCL	BBF	BBF		MCL	MCL	BBF	BBF
18	R	32.5	33.1	32.0	34.0	R	31.0	31.9	30.6	32.6
	L	32.6	33.4	32.3	33.3	L	30.9	32.3	30.5	31.6
19	R	32.1	32.2	31.8	32.5	R	31.0	31.7	30.7	31.8
	L	32.0	31.9	31.6	32.8	L	30.9	31.3	30.5	31.9
20	R	31.3	32.6	31.1	32.5	R	31.3	32.1	30.9	32.4
	L	31.2	32.8	31.1	32.9	L	30.9	32.3	31.3	32.9
21	R	30.1	32.2	29.7	31.6	R	29.4	31.3	29.4	31.1
	L	30.1	32.2	29.4	31.6	L	29.2	31.2	29.3	31.1
22	R	30.1	30.6	30.0	31.6	R	32.2	32.9	32.1	33.0
	L	30.0	31.2	30.4	30.6	L	31.9	32.9	31.8	32.4
23	R	28.5	30.7	28.2	30.1	R	31.6	32.4	31.3	31.8
	L	28.3	31.1	28.4	30.5	L	31.4	32.4	31.2	32.2
24	R	30.1	31.9	29.9	32.1	R	30.3	31.5	29.9	30.8
	L	29.9	31.7	29.5	31.6	L	29.9	30.9	29.9	30.7
25	R	31.4	32.5	31.1	32.4	R	31.8	32.4	31.2	32.0
	L	31.1	32.1	31.2	32.7	L	31.7	32.0	31.4	32.4
26	R	31.2	32.4	30.8	31.6	R	30.8	31.7	30.4	30.7
	L	31.2	32.3	31.0	31.7	L	30.4	31.6	30.3	31.0
27	R	30.0	32.0	31.3	32.9	R	31.4	33.6	30.4	34.6
	L	29.4	31.4	31.0	32.9	L	30.8	33.1	30.6	33.9
28	R	31.0	31.7	31.5	32.7	R	29.4	29.7	29.7	30.3
	L	31.1	32.1	31.5	32.2	L	29.6	29.8	29.6	30.2
29	R	30.8	32.1	31.6	33.4	R	31.1	33.0	30.5	33.3
	L	30.3	32.4	31.2	33.1	L	30.3	32.7	31.2	33.4

APPENDIX E (continued)

Subject		Ankles Untaped 1 MCL	2 MCL	1 BBF	2 BBF		Ankles Taped 1 MCL	2 MCL	1 BBF	2 BBF
30	R	30.9	32.1	30.6	32.1	R	31.5	32.3	30.3	31.9
	L	30.6	32.6	30.7	32.4	L	31.1	33.3	31.8	32.8
31	R	30.7	31.1	31.2	32.6	R	30.8	31.9	31.5	33.6
	L	30.7	31.1	31.1	33.4	L	31.0	32.6	31.9	33.6
32	R	30.4	31.4	30.7	31.2	R	30.7	31.2	30.1	31.1
	L	30.6	31.4	30.6	31.5	L	30.6	30.8	30.3	31.4
33	R	31.1	31.9	30.6	31.6	R	30.7	32.3	30.4	32.0
	L	30.8	31.4	30.2	31.8	L	30.8	31.9	30.1	32.5
34	R	31.7	32.4	32.0	32.7	R	31.4	32.0	31.0	32.0
	L	31.9	32.3	32.1	32.7	L	31.2	31.6	31.0	31.9
35	R	32.0	32.9	31.9	33.4	R	30.2	31.4	29.6	30.7
	L	31.8	32.9	32.0	32.9	L	29.8	31.3	29.7	30.7
36	R	32.4	33.0	31.6	33.5	R	32.3	32.7	31.9	33.6
	L	32.4	32.8	31.7	33.5	L	32.2	32.5	31.5	33.5
37	R	29.5	32.0	29.4	31.0	R	30.5	31.7	29.6	31.1
	L	29.7	31.6	29.8	31.0	L	30.1	31.1	29.6	31.3
38	R	31.5	32.5	31.9	33.4	R	32.1	32.7	31.9	33.1
	L	30.7	31.8	31.1	32.4	L	31.6	32.4	31.7	32.8
39	R	30.6	32.4	30.3	32.1	R	30.0	31.7	29.2	31.3
	L	30.6	32.1	29.9	31.8	L	29.4	31.3	29.0	31.2
40	R	30.7	31.4	30.3	32.1	R	32.2	33.2	31.8	33.2
	L	30.2	31.2	30.6	31.8	L	32.2	32.8	32.2	33.2
41	R	30.9	32.6	30.4	31.7	R	32.3	33.3	31.5	32.8
	L	30.7	31.6	30.6	32.8	L	32.2	32.5	32.3	33.8

APPENDIX E (continued)

Subject		Ankles Untaped 1 MCL	2 MCL	1 BBF	2 BBF		Ankles Taped 1 MCL	2 MCL	1 BBF	2 BBF
42	R	30.0	31.2	30.6	33.1	R	32.0	32.8	31.6	33.4
	L	29.1	30.1	30.7	32.6	L	31.9	32.4	31.6	33.3
43	R	31.5	31.9	30.9	32.0	R	30.6	31.7	31.2	32.3
	L	31.3	31.7	31.4	32.3	L	30.4	31.7	30.6	32.6
44	R	29.1	29.7	29.2	30.0	R	31.2	32.0	31.6	31.7
	L	28.7	29.4	28.8	30.1	L	30.9	31.7	31.6	31.4
45	R	29.8	31.2	30.0	32.0	R	30.6	31.2	30.7	32.4
	L	30.0	31.5	30.0	32.1	L	30.7	31.7	31.1	32.7
46	R	28.8	30.9	28.7	31.1	R	27.7	29.8	27.2	29.9
	L	28.9	30.9	28.8	31.3	L	28.2	30.1	27.7	30.2
47	R	31.5	32.7	30.7	33.4	R	32.4	33.0	31.4	33.4
	L	31.4	33.2	30.9	33.3	L	31.9	33.5	31.7	33.8
48	R	31.8	31.9	31.0	31.6	R	30.4	30.6	30.2	30.6
	L	31.6	32.2	31.4	31.7	L	30.2	30.7	30.5	31.1
49	R	31.2	32.0	30.9	32.6	R	30.8	32.5	30.5	31.9
	L	31.1	32.3	31.3	33.1	L	30.6	32.3	30.9	32.6
50	R	29.1	31.0	29.8	31.1	R	30.1	31.5	30.5	31.7
	L	29.4	31.1	29.4	31.1	L	30.3	31.1	30.3	31.3
51	R	31.7	33.0	30.8	32.3	R	29.3	31.1	28.9	30.9
	L	31.6	32.4	30.7	32.1	L	29.1	30.9	29.1	31.0
52	R	30.7	31.5	29.9	30.7	R	30.9	32.8	30.2	31.8
	L	30.1	30.8	30.2	30.8	L	30.6	32.5	30.6	31.6

APPENDIX E (continued)

Subject		Ankles Untaped 1 MCL	2 MCL	1 BBF	2 BBF		Ankles Taped 1 MCL	2 MCL	1 BBF	2 BBF
53	R	29.6	32.7	30.1	31.9	R	29.6	32.4	30.2	31.7
	L	29.3	31.7	30.7	31.6	L	29.8	31.4	30.4	30.9
54	R	30.3	30.0	30.4	31.0	R	30.2	31.5	30.6	31.8
	L	30.4	31.1	30.5	31.7	L	30.6	31.8	31.0	32.3
55	R	29.9	31.2	29.4	30.9	R	28.7	31.1	28.2	30.8
	L	29.6	30.6	29.9	30.8	L	28.5	30.8	28.5	30.2
56	R	30.6	31.3	30.5	30.6	R	30.6	31.8	30.1	31.9
	L	29.8	31.0	30.4	30.6	L	30.2	30.9	30.1	33.1
57	R	31.5	33.0	32.0	33.4	R	30.1	30.6	30.7	31.4
	L	31.8	33.6	31.9	33.5	L	30.2	31.2	30.7	31.2
58	R	33.2	33.8	33.1	33.1	R	31.4	32.2	31.4	32.1
	L	33.1	33.4	33.1	33.6	L	31.6	32.2	31.3	32.2
59	R	32.3	32.8	32.1	33.4	R	31.9	33.3	32.0	33.8
	L	32.0	33.0	32.2	33.4	L	31.9	33.1	31.8	33.6
60	R	31.7	32.1	31.0	32.2	R	31.2	32.5	30.8	31.9
	L	31.5	32.0	31.3	32.8	L	30.8	32.1	30.8	32.5

VITA

D. Ray Collins, son of Mr. and Mrs. W. A. Collins, was born on April 23, 1942, in Greeneville, Tennessee. He attended public school in Greene County, Tennessee and graduated from St. James High School in 1960.

After serving six months of active duty in the United States Army Reserve, the author entered Tusculum College (Greeneville, Tennessee) in September, 1961. While a student at Tusculum, he was recognized as a Charles Oliver Gray Scholar for scholastic achievement and selected to the 1964 All-Volunteer State Athletic Conference baseball team. In May, 1965, the author received the Bachelor of Science degree from Tusculum College with a major in secondary education and minors in English and physical education.

From August, 1965 to May, 1967, Collins served as Dean of Boys, teacher, and baseball coach at Washington College Academy, Washington College, Tennessee. During the summers from 1965 to 1967, he attended the University of Tennessee as a candidate for the Master of Science degree in physical education. The degree was awarded in August, 1967.

During the 1967-68 school year, the author served as a graduate assistant in the School of Health, Physical Education, and Recreation at Indiana University while completing the requirements for the Director of Physical Education degree. Upon completion of this degree, he accepted a position as Assistant Professor and Department Chairman of Health and Physical Education at Wytheville Community College, Wytheville, Virginia and served in that capacity until June, 1970.

In June, 1970, the author matriculated at Louisiana State University to work toward the Doctor of Education degree with a major in physical education and a minor in educational administration. He served as a graduate assistant for two years, one as a teaching assistant and the other as a research assistant.

The author is married to the former Phyllis L. Cutshall of Greeneville, Tennessee.

EXAMINATION AND THESIS REPORT

Candidate: D. Ray Collins

Major Field: Physical Education

Title of Thesis: Effects of Ankle Taping Upon Strength Decrement and Surface Temperature of Knee Flexors and Extensors in Submaximal Treadmill Running

Approved:

Jack K. Nelson
Major Professor and Chairman

Max Goodrich
Dean of the Graduate School

EXAMINING COMMITTEE:

[illegible]

Malcolm L. Patterson

[illegible]

Ralph E. Stehin

Date of Examination:

July 17, 1972